

THIRTY-FIRST ANNUAL REPORT
OF THE
ONTARIO DEPARTMENT OF MINES
1922

PARTS I AND II

DEPARTMENT OF MINING ENGINEERING

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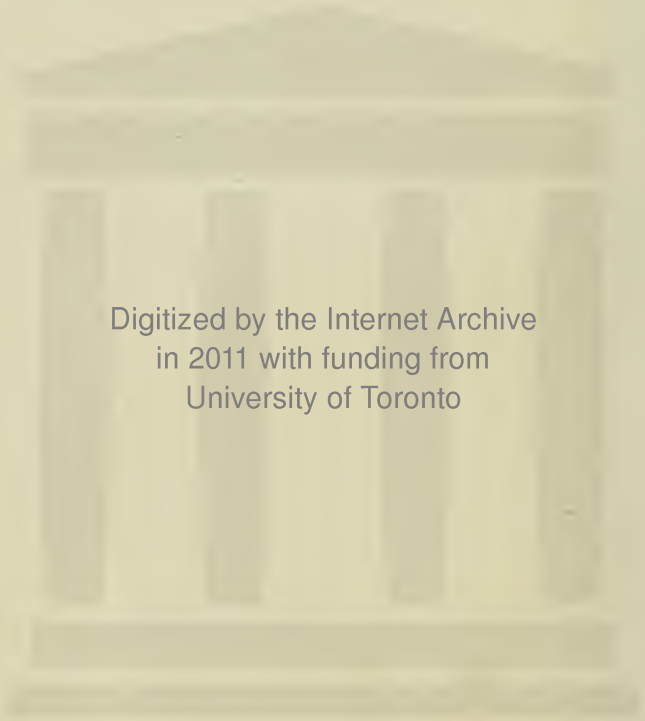
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PROVINCE OF ONTARIO
DEPARTMENT OF MINES

HON. H. MILLS, MINISTER OF MINES

THOS. W. GIBSON, DEPUTY MINISTER

THIRTY-FIRST ANNUAL REPORT
OF THE
ONTARIO DEPARTMENT OF MINES

BEING
VOL. XXXI, PART I, 1922

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LETTER OF TRANSMISSION

TO HIS HONOUR, HENRY COCKSHUTT,

Lieutenant-Governor of the Province of Ontario.

SIR,—I have the honour to transmit to you herewith, for presentation to the Legislative Assembly of the Province of Ontario, the Thirty-first Annual Report of the Department over which I have the honour to preside.

I have the honour to be, Sir,

Your obedient servant,

HENRY MILLS,
Minister of Mines.

Department of Mines,
Toronto, 1923.

Introductory Letter

TO THE HONOURABLE H. MILLS,
Minister of Mines.

SIR:—

I beg to submit to you herewith the Thirty-first Annual Report of the Department of Mines. The Report comprises ten parts, published separately, as follows:—

PART 1.—Statistical Review of the Mining Industry of Ontario, with a variety of Tables illustrating the course of the industry during the year 1921, by W. R. Rogers; also Gravel Deposits in the St. Clair River, by James Bartlett, Inspector of Mines. The St. Clair River is an important source of these materials for road building and other construction purposes.

PART 2.—Geology of the Mine Workings of Cobalt and South Lorrain Silver Areas, by C. W. Knight, Associate Provincial Geologist, together with a description of mining and metallurgical practice in treatment of silver ores at Cobalt by Fraser D. Reid, James J. Denny and R. H. Hutchison. Mr. Knight made an extended and thorough investigation into the structural conditions of the mines of Cobalt, as revealed in the underground workings, and particularly into the relationships existing between the ore bodies and the surrounding rocks. In presenting his conclusions, Mr. Knight also brings together a mass of interesting material regarding one of the richest and most remarkable silver areas ever discovered. Particulars are also given of the valuable deposits being uncovered in South Lorrain at the time the Report was written.

PART 3.—The Blanche River Area, with Map No. 31b, by A. G. Burrows and P. E. Hopkins.

PART 4.—Fourth Report of Joint Peat Committee, by B. F. Haanel, Secretary.

PART 5.—Natural Gas and Petroleum in 1921, by R. B. Harkness, Natural Gas Commissioner.

PART 6.—Geology and Minerals of the County of Leeds, with Map No. 31c, by Prof. M. B. Baker, of Queen's University, Kingston.

PART 7.—Geology of the Watabeag Area, with Map No. 31d, by Douglas G. H. Wright.

PART 8.—Iron Formation of Lake St. Joseph, with Maps Nos. 31e and 31f, by Prof. E. L. Bruce, of Queen's University, Kingston.

PART 9.—The Stratigraphy and Paleontology of Toronto and Vicinity (Part III.—Gastropoda, Cephalopoda and Vermes, with six plates), by Prof. W. A. Parks and Madeleine Fritz, of the University of Toronto.

PART 10.—Mining Accidents in 1921, and Mines of Ontario, by T. F. Sutherland, Chief Inspector of Mines, and Inspectors G. E. Cole, James Bartlett, J. G. McMillan and A. R. Webster; also Instruction Classes for Prospectors, by Dr. W. L. Goodwin, and Notes on Clays of the Missinaibi River, by Joseph Keele.

I venture to think that the series of Reports contained in Volume XXXI, makes a substantial addition to the existing stock of information regarding the mining industry and mineral resources of Ontario.

I have the honour to be, Sir,

Your Obedient servant,

THOS. W. GIBSON,

Deputy Minister of Mines.

DEPARTMENT OF MINES,
Toronto, 1923.

STATISTICAL REVIEW OF ONTARIO'S MINERAL INDUSTRY IN 1921.

By W. R. Rogers.

The mining industry as a whole, in common with most other lines of business, experienced a year of depression. Post-war conditions have been reflected in the fluctuating values obtained for mineral products. The general deflation in commodity prices experienced in 1919 was followed during the greater part of 1920 by a return to higher levels. In 1921 most branches of the industry again passed through a period of deflation, and prices in some cases returned to pre-war levels. This condition is exemplified in the case of nickel, copper and pig iron. Some non-metallics which may be classed as war minerals experienced a decrease in output and lowering of prices. In the building industries there are evidences of a revival, brought about in part by a decline in cost of materials.

A scheme of co-operation has been effected with the Dominion Bureau of Statistics, Ottawa, whereby uniform blank forms are used in collecting statistics. This saves the operators expense and inconvenience, the same forms serving both statistical bureaus.

During the war period attention was directed largely to the production of war metals such as nickel, copper, iron and molybdenum. Subsequently the demand slackened, more particularly as regards nickel and copper. Owing to an over-stocked market and consequent low prices, the nickel-copper producing companies curtailed operations or shut down entirely, pending the absorption of surplus stock. Meantime, as nickel requirements for armament purposes had declined, new uses for nickel were being investigated with a view to extending the market for the industrial consumption of this metal. Ontario, which produces 90 per cent. of the world's nickel supply, is vitally interested in the success of the nickel industry.

The outstanding feature in Ontario's mineral industry is the growing importance of the Province as a producer of gold. The situation for gold-mining companies improved greatly during the year. Labour became more plentiful, more efficient and cheaper; costs of supplies declined and gold commanded a premium. The exchange premium, however, which was at its maximum at the beginning of the year declined gradually, and is still declining. This, however, is not a factor on which the success or failure of the gold-mining industry in this Province depends. Every indication points to greatly increased gold production in the future. A shortage of hydro-electric power curtailed the output in the spring of 1921.

Details regarding output and conditions in the several phases of the mining industry are noted under separate headings. The value of metalliferous production exceeded that of any pre-war year, while the non-metallic valuation was the greatest in Ontario's history. Table I, which follows, gives a summary of Ontario's mineral production in 1921, together with the number of employees and wages paid to workmen by operators. Table II on page 3 shows the valuation itemized for the last quinquennial period.

TABLE 1.—SUMMARY OF MINERAL STATISTICS OF ONTARIO FOR 1921

Product	Quantity	Value	Employees	Wages
METALLIC:		\$		\$
Gold..... ounces	710,812	14,692,357	2,761	4,368,070
Silver..... "	8,435,593	5,673,908	1,074	1,440,144
Copper in matte (a)..... short tons	3,686	737,142	1,895	1,557,696
Nickel in matte (a)..... "	4,850	1,939,851		
Iron ore (b)..... "	100	459	44	68,859
Iron, pig (c)..... "	66,316	1,588,751	391	620,938
Lead, pig..... lbs.	3,576,222	191,113	15	17,830
Copper..... "	3,131,762	364,588	(d) 454	367,216
Nickel, metallic..... "	5,430,147	1,825,359		
Nickel oxide..... "	1,402,019	285,391	(e) 225	325,466
Platinum metals..... ounces	13,418	862,034		
Cobalt, metallic and in residues..... lbs.	38,544	147,952		
Cobalt oxide..... "	165,554	354,418		
Other Cobalt and Nickel compounds..... "	111,178	114,258		
Total metallic.....		28,777,581	6,859	8,766,219
NON-METALLIC:				
Actinolite..... tons.	78	975	6	215
Arsenic, white..... "	1,491	233,763	(e)	(e)
Clay products—(\$5,183,125).				
Brick, common..... M.	114,583	2,025,643	1,703	1,369,731
Brick, fancy and pressed..... "	58,904	1,241,375		
Tile, drain..... "		397,104		
Tile, building and floor tile..... tons.		421,127		
Pottery..... "		69,984	24	28,502
Sewer pipe..... "		939,463	230	272,837
Cement, Portland..... bbls.	2,723,071	6,424,356	883	1,228,460
Corundum..... tons	403	55,965	34	16,885
Feldspar..... "	20,115	150,457	82	95,469
Fluorspar..... "	116	1,744	5	132
Graphite, crude and refined..... "	899	63,439	32	13,198
Gypsum, crushed, ground and calcined..... "	84,790	433,053	109	122,549
Iron pyrites..... "	27,785	101,306	96	97,653
Lime—				
Quicklime..... bush.	2,763,062	962,439	366	341,826
Hydrated..... tons	26,862	381,749		
Mica..... "	218	28,891	28	23,539
Mineral water..... Imp. gals.	308,647	14,438	1	923
Natural gas..... M. cu. ft.	8,532,234	2,975,502	554	504,497
Peat..... tons	1,666	6,664	18	11,662
Petroleum, crude..... bbls.	172,859	559,198	147	149,395
Quartz and silica brick..... tons	72,068	220,806	109	49,017
Salt..... "	161,987	1,649,626	264	311,205
Sand and gravel..... "	6,273,173	1,496,729	307	228,628
Sand-lime brick..... M	36,482	534,531	131	141,460
Stone, building, trap, granite, etc..... tons	2,716,080	4,167,582	809	702,507
Talc, crude and ground..... "	9,967	140,390	30	41,978
Total non-metallic.....		25,786,728	5,968	5,752,268
Add metallic.....		28,777,581	6,859	8,766,219
Grand total.....		54,564,209	12,827	14,518,487

(a) Copper and nickel in the matte valued at 10 and 20 cents per pound respectively.

(b) Exports and shipments to points other than Ontario blast furnaces. Total shipments of iron ore, 58,499 tons, valued at \$227,134.

(c) Production from Ontario ore only. Total output of blast furnaces, 494,901 tons of pig iron, worth \$11,856,352.

(d) Employees and wages for nickel-copper refineries.

(e) Employees and wages for silver-cobalt smelters and refineries.

The following comparative statement shows the course of the mining industry during the five-year period, 1917 to 1921 inclusive, as indicated by the value of the total production:

TABLE II.—VALUE OF MINERAL PRODUCTION, 1917 TO 1921.

Product.	1917	1918	1919	1920	1921
METALLIC:	\$	\$	\$	\$	\$
Gold.....	8,698,735	8,502,480	10,451,709	11,686,043	14,692,357
Silver.....	16,183,208	17,415,882	12,904,312	10,873,496	5,763,908
Platinum metals.....			200,000	1,996,535	862,034
Cobalt (a).....	1,122,779	1,615,130	868,107	1,603,736	502,370
Nickel (b).....	21,041,956	27,840,422	11,925,220	15,689,131	4,050,601
Other Nickel and Cobalt compounds.....	42,026	73,347	188,083	16,959	114,258
Copper, metallic and in matte.....	7,961,662	8,532,790	3,709,687	3,970,744	1,101,730
Iron ore (c).....	483,690	624,364	48,341	60,981	459
Pig iron (d).....	1,016,699	1,364,736	1,200,793	2,204,205	1,588,751
Lead (pig).....	172,601	149,841	94,507	179,714	191,113
Molybdenite.....	108,501	59,067			
Metallic production.....	56,831,857	66,178,059	41,590,759	48,281,553	28,777,581
NON-METALLIC:					
Actinolite.....	1,320	2,508	1,176	1,160	975
Arsenic.....	608,483	566,332	485,360	432,434	233,763
Asbestos.....	2,150				
Barite.....		900			
Brick, common.....	800,983	756,962	2,334,526	2,617,031	
Brick, sand-lime.....					534,531
Brick, fancy, and pressed.....	474,614	396,698	539,908	809,126	
Cement, Portland.....	2,934,271	1,910,839	3,659,720	4,377,814	6,424,356
Corundum.....	31,213	26,120		27,000	55,965
Feldspar.....	81,802	111,173	88,663	268,295	150,457
Fluorspar.....	66,474	153,190	60,389	67,381	1,744
Graphite.....	296,587	208,848	99,841	132,882	63,439
Gypsum.....	130,138	151,564	278,111	404,162	433,053
Iron pyrites.....	1,111,264	1,144,737	366,422	618,283	101,306
Lime.....	657,364	872,177	1,268,290	1,799,763	1,344,188
Mica.....	92,453	49,575	56,199	54,169	28,891
Mineral water.....	(e)	133,808	19,290	15,059	14,438
Natural gas.....	3,220,123	2,498,769	2,583,324	3,163,500	2,975,502
Peat fuel.....			1,750	15,600	6,664
Petroleum (crude).....	475,000	781,097	632,789	724,145	559,198
Phosphate of lime (apatite).....			31		
Pottery.....	94,501	88,275	119,551	127,049	
Quartz (silica).....	358,674	452,711	179,070	366,441	220,806
Salt.....	1,047,707	1,287,039	1,395,368	1,544,867	1,649,626
Sand and gravel.....	431,597	553,638	501,666	1,390,704	1,496,729
Sewer pipe.....	378,923	362,536	609,100	860,811	
Stone, building, crushed, etc.....	939,052	869,239	1,230,922	3,944,972	4,167,582
Tale, crude and ground.....	179,554	246,691	240,399	306,319	140,390
Tile, drain.....	546,040	309,899	354,700	359,373	
Tile, building and roofing.....	301,688	195,588	186,592	369,530	
Non-metallic production.....	15,261,975	14,130,913	17,293,157	24,797,969	25,786,728
Add metallic production.....	56,831,857	66,178,059	41,590,759	48,281,553	28,777,581
Total production.....	72,093,832	80,308,972	58,883,916	73,079,522	54,564,209

(a) Cobalt oxide, metallic cobalt, and cobalt content of residues marketed.

(b) Nickel in matte, oxide and metallic nickel.

(c) Exports and shipments to points other than Ontario blast furnaces.

(d) Product from Ontario ore only.

(e) Production figures not collected.

In Table III is given the aggregate value of the metals and metallic products since the several substances began to be produced in Ontario down to the end of 1921. It should be pointed out that since 1914 the statistics of annual production credit pig iron only with the value of the pig iron product made from Ontario ore. This is but a small part of the total output, since the great bulk of the iron ore charged into the blast furnaces of the Provinces is "lake" ore from the mines of Michigan, Minnesota and Wisconsin. Conversely, part of the iron ore raised in Ontario is exported to the United States in the form of briquettes produced from low-grade magnetite ores. In the production tables credit is taken only for the ore exported or shipped to points other than Ontario blast furnaces, since to include the value of the domestic ore converted into pig iron in Ontario furnaces would involve a duplication of this item.

TABLE III.—VALUE OF TOTAL PRODUCTION OF METALS IN ONTARIO.

Metal or Product	Production to 31st December, 1920	Production, 1921	Production to 31st December, 1921
	\$	\$	\$
Gold.....	73,192,873	14,692,873	87,885,230
Silver.....	208,805,398	5,673,908	214,479,306
Platinum metals.....	3,496,535	862,034	4,358,569
Cobalt, including Cobalt oxide.....	8,390,742	502,370	8,893,112
Nickel, including Nickel oxide.....	165,624,893	4,050,601	169,675,494
Other Cobalt and Nickel compounds.....	435,819	114,258	550,077
Copper.....	57,627,511	1,093,850	58,721,361
Iron ore.....	9,411,234	459	9,411,693
Pig iron.....	82,330,915	1,588,751	83,919,666
Lead.....	784,816	191,113	975,929
Zinc ore.....	92,410		92,410
Molybdenite.....	209,735		209,735
Total.....	610,402,881	28,777,581	639,180,462

Gold

Ontario's gold production of \$14,692,357 in 1921 was nearly three million dollars or over 25 per cent. in excess of the 1920 output. During the last quarter of the year bullion worth \$4,832,305 was produced, or at the rate of \$19,329,220 per annum. With considerably augmented milling capacity at both Porcupine and Kirkland Lake the 1922 production is expected to show a marked increase over 1921. From 1904 to 1919 Ontario's output of silver exceeded gold in valuation, but in 1920 this position was reversed. During the first quarter of 1921 the gold mines were unable to operate to capacity owing to hydro-electric power shortage; otherwise the year's showing would be still more satisfactory. Operating conditions are steadily improving both as regards labour and supplies.

The Wright-Hargreaves at Kirkland Lake started its 175-ton mill in May and an initial dividend of 5 per cent. was paid on January 1st, 1922. In the same area the Ontario-Kirkland, another new producer, tuned up its 110-ton mill in December, and cyaniding was under way by the middle of January, 1922.

Expansion of milling capacity at Porcupine has been deterred by reason of the uncertainty of an adequate hydro-electric power supply. The Northern Canada Power Company has recently come to an agreement with the McIntyre mine to take over the latter's power rights at Sturgeon falls on the Mattagami river. 28 miles to the north of Porcupine, where a development of 7,000 horsepower is possible. Work will proceed at once and power should be available by the end of 1922, thereby increasing Porcupine's power supply by about 50 per cent. An increase

of milling capacity from 550 to 800 tons is proceeding at the McIntyre. The Hollinger, which was treating about 4,000 tons of ore daily at the end of the year, also plans greater capacity, but additional power will be necessary, so application has been made to the Ontario Government for a waterpower lease at a point on the Abitibi river, 12 miles north of Cochrane.

The following operators produced gold in 1921:

PRODUCING GOLD MINES, 1921

Name of Company.	Name of Mine.	Locality.	P.O. Address of Manager, etc.
Argonaut Gold, Limited.	Argonaut.	Gauthier tp.	Dane.
Dome Mines Company, Limited.	Dome and Dome Extension.	Porcupine.	South Porcupine.
Hollinger Consolidated Gold Mines, Limited.	Hollinger.	Porcupine.	Timmins.
Kirkland Lake Gold Mining Company, Limited.	Kirkland Lake.	Kirkland Lake.	Kirkland Lake.
Lake Shore Mines, Limited.	Lake Shore.	Kirkland Lake.	Kirkland Lake.
McIntyre Porcupine Mines, Limited.	McIntyre.	Porcupine.	Schumacher.
Northerown Porcupine Mines, Ltd.	Northerown.	Porcupine.	Timmins.
Pilon, A., and Richards, M.	T.B., 1471-2.	Sturgeon Lake.	Northpines.
St. Anthony Mine Syndicate.	St. Anthony.	Sturgeon Lake.	Toronto.
Teck-Hughes Gold Mines, Limited.	Teck-Hughes.	Kirkland Lake.	Kirkland Lake.
Wright-Hargreaves Mines, Limited.	Wright-Hargreaves.	Kirkland Lake.	Kirkland Lake.

Details of production are given in the table which follows:

ONTARIO'S GOLD PRODUCTION, 1921.

Source	Ore Milled, tons	Bullion shipped				Total Value Bullion
		Gold		Silver		
		Fine ounces	Value	Fine ounces	Value	
PORCUPINE						
Dome.....	335,680	110,316	2,280,237	15,628	10,027	2,290,264
Hollinger Consolidated.....	1,072,493	435,404	8,999,796	80,911	51,480	9,051,276
McIntyre.....	172,287	87,837	1,815,597	20,321	12,164	1,827,761
Northerown.....		382	7,896	69	47	7,943
Total.....	1,580,460	633,939	13,103,526	116,929	73,718	13,177,244
KIRKLAND LAKE						
Kirkland Lake.....	43,966	11,678	241,379	1,665	1,037	242,417
Lake Shore.....	21,817	23,896	493,940	2,025	1,336	495,276
Teck-Hughes.....	34,693	15,582	322,028	1,305	891	322,919
Wright-Hargreaves.....	36,053	22,617	467,504	2,066	1,248	468,751
Total.....	136,529	73,773	1,524,851	7,061	4,512	1,529,363
MISCELLANEOUS						
Argonaut.....	Clean-up	25	510	4	3	513
Pilon and Richards.....	30	54	1,113	12	9	1,122
St. Anthony—						
1920*.....		420	8,688	82	83	8,771
1921.....	320	243	5,032	59	36	5,068
Nickel-Copper refining.....		2358	48,637	.....	.....	48,637
Total.....	350	3100	63,980	157	131	64,111
GRAND TOTAL.....	1,717,339	710,812	14,692,357	124,147	78,361	14,770,718

*Not previously reported.

Exchange on New York funds averaged 11.61 per cent. for the year as compared with 12.27 in 1920. Ontario gold producers, in addition to the values given in the table on page 5, received \$1,359,636 by way of exchange premium.

In the following table the total gold output of the Province is given, also that from Porcupine and Kirkland Lake beginning in 1910 and 1913 respectively:—

TABLE V.—TOTAL GOLD PRODUCTION OF ONTARIO

Year	Total Production	Porcupine		Kirkland Lake	
		Value \$	Per Cent.	Value \$	Per Cent.
1866-1891.....	190,258*				
1892-1909.....	2,509,492				
1910.....	68,498	35,539	51.8		
1911.....	42,637	15,437	36.2		
1912.....	2,114,086	1,730,628	81.8		
1913.....	4,558,518	4,294,113	94.1	65,260	1.2
1914.....	5,529,767	5,190,794	93.8	114,154	2.0
1915.....	8,501,391	7,536,275	88.6	551,069	6.5
1916.....	10,339,259	9,397,536	90.8	702,761	6.8
1917.....	8,698,735	8,229,744	94.5	404,346	4.6
1918.....	8,502,480	7,767,907	91.4	632,007	7.4
1919.....	10,451,709	9,941,804	95.1	486,809	4.7
1920.....	11,686,043	10,597,573	90.7	1,033,478	8.8
1921.....	14,692,357	13,103,526	89.3	1,524,851	10.4
Total.....	87,885,230	77,840,876	88.6	5,514,735	6.3

*Estimated.

Dividends.—The important period of gold mining in Ontario began with the opening of the Porcupine mines in 1910. Since that time the gold mines have paid out in returns to shareholders a total of \$23,140,734.85, details of which are given in Table VI.

TABLE VI.—DIVIDENDS AND BONUSES PAID BY GOLD MINING COMPANIES TO DECEMBER 31, 1921.

Name of Company	Date of Incorporation	Authorized Capital	Capital Stock Issued	Par value per share	Amount of Dividends and Bonuses paid to end of 1920	Amount of Dividends and Bonuses paid during 1921	Rate per cent.	Total of Dividends and Bonuses paid to Dec. 31st, 1921	Date when last Dividend or Bonus paid
*Dome Mines Company, Ltd	Mar. 23, 1910	\$ 5,000,000	\$ 4,766,670	\$ c. 10 00	\$ c. 1,916,886 00	\$ c. 474,525 75	10	\$ c. 2,391,411 75	Oct. 20, 1921
†Hollinger Cons. Gold Mines, Ltd.	May 25, 1916	25,000,000	24,600,000	5 00	13,360,000 00	3,198,000 00	13	16,558,000 00	Dec. 31, 1921
Lake Shore Gold Mines, Ltd.	Feb. 25, 1914	2,000,000	2,000,000	1 00	280,000 00	120,000 00	6	400,000 00	Nov. 10, 1921
McIntyre-Poreupine Mines, Ltd.	Mar. 16, 1911	4,000,000	3,640,283	1 00	1,994,655 65	546,042 45	15	2,540,698 10	Sept. 1, 1921
Poreupine Crown Mines, Ltd.	May 26, 1913	2,000,000	2,000,000	1 00	840,000 00	.....	.....	840,000 00	July 15, 1917
Rea Consolidated Gold Mines.	April 5, 1911	1,000,000	200,000	5 00	12,000 00	.....	.....	12,000 00	.....
Tough-Onakes Gold Mines, Ltd.	July 15, 1913	3,000,000	2,657,500	5 00	398,625 00	.....	.....	398,625 00	Dec. 27, 1916
Total.	.....	.....	.....	.....	18,802,166 65	4,338,568 20	.....	23,140,734 85	.....

* Dividends in 1921 include \$4,079 paid to former Dome Extension shareholders.

† Hollinger Consolidated Gold Mines, Limited, is a consolidation of the Acme Gold Mines, Limited, Millerton Gold Mines, Limited, and Hollinger Gold Mines, Limited. Dividends include \$160,000 paid by Acme prior to the amalgamation.

Silver—Cobalt

Although the price of silver dropped from an average of 100.90 cents in 1920 to 62.65 in 1921, production was well maintained. Several mines which were forced to close down in the fall of 1920 owing to power shortage have not reopened. In South Lorrain the Keeley mine has struck rich ore and is producing concentrates in its new mill. The adjoining Frontier mine, which has been optioned by the Mining Corporation of Canada, was also a producer. During the year an underground survey of silver mines at Cobalt and South Lorrain was completed by C. W. Knight, Associate Provincial Geologist. His report will appear as Volume XXXI, Part 2.

Mines shipping over a quarter million ounces of silver in 1921 are given in order:

Mine.	Ounces.
Nipissing.....	3,012,680
O'Brien.....	1,366,686
Coniagas.....	1,301,860
Mining Corporation of Canada.....	911,899
La Rose.....	658,423
Keeley.....	281,659

In addition to the silver content of ores, concentrates, residues, etc., producing mines are paid for the cobalt content provided the percentage is sufficiently high. Mine shippers in 1921 were paid \$48,512 for 185,442 pounds of cobalt.

From weekly statements, issued by the General Freight and Passenger Agent of the Temiskaming and Northern Ontario Railway, showing railway shipments of ore, concentrates, etc., from the Cobalt area the following information has been compiled: Total shipments, 2,616 tons of which 1,479 were consigned to southern Ontario and 1,137 tons to United States smelters and refineries.

Classified according to source, the output of silver in 1921 was derived as follows:

	Ounces.
Cobalt.....	7,673,535
South Lorrain.....	328,886
Gowganda.....	258,292
Casey township.....	1,101
James township (Elk Lake).....	117
Recovered from gold ores.....	124,147
Recovered from nickel-copper refining.....	49,515
Total.....	8,435,593

The producers of silver are given in the following list:—

SILVER PRODUCERS IN 1921

Operator.	Mine or Source.	Location.
Aladdin Cobalt Company, Limited.....	Chambers-Ferland.....	Cobalt.
Bailey Silver Mines, Limited.....	Bailey and Silver Cliff.....	Cobalt.
Beaver Consolidated Mines, Limited.....	Beaver.....	Cobalt.
Bennett, N. W.....	Casey-Cobalt mill clean-up.....	Casey tp.
Benson, G. H.....	Silver Leaf dump.....	Cobalt.

TABLE VIII.—TOTAL SHIPMENTS FROM SILVER MINES, SMELTERS AND REFINERIES, 1904 TO 1921.

Year	Copper (a)		Lead (a)		Nickel (b)		Cobalt (c)		Arsenic		Silver		Total Value
	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Ounces	Value	
1904		\$		\$	14	3,467	16	19,960	72	903	206,875	111,887	\$
1905					75	10,000	118	100,000	549	2,693	2,451,356	1,360,503	136,217
1906					160		321	80,704	1,440	15,858	5,401,766	3,667,551	1,473,196
1907					370	1,174	739	104,426	2,958	40,104	10,023,311	6,155,391	3,764,113
1908					612		1,224	111,118	3,672	40,373	19,437,875	9,133,378	6,301,095
1909					766		1,533	94,965	4,294	61,039	25,897,825	12,461,576	9,284,869
1910					504		1,098	54,699	4,897	70,709	30,645,181	15,478,047	12,617,580
1911					392		852	170,890	3,806	74,609	31,507,791	15,953,847	15,603,455
1912					429	14,220	934	314,381	4,166	80,546	30,243,859	17,408,935	16,199,346
1913					377	13,326	821	420,386	3,663	64,146	29,681,975	16,553,981	17,818,082
1914 (d)					90	28,978	351	590,406	2,030	116,624	25,162,841	12,765,461	17,051,839
1915					35	28,353	206	383,261	2,490	148,379	24,746,534	12,135,816	13,501,469
1916					79	59,380	400	805,014	2,160	200,103	19,915,090	12,643,175	12,695,809
1917	53	28,840			155	125,071	337	1,138,190	2,592	608,483	19,401,893	16,121,013	13,707,672
1918	72	35,712	3	453	186	156,893	380	1,640,310	2,545	566,332	17,661,694	17,341,790	18,021,597
1919	110	40,976	12	1,296	276	188,418	298	1,019,479	2,834	485,300	11,214,317	12,738,994	19,741,490
1920	50	17,494	5	792	127	93,233	283	1,605,365	1,883	431,527	10,846,321	10,654,471	14,474,523
1921	103	34,504	3	270	10	7,965	126	616,235	1,491	233,763	8,261,931	5,564,594	12,802,882
Total	388	157,526	23	2,811	4,657	730,178	10,037	9,269,789	47,542	3,241,551	322,708,435	198,250,410	211,652,265

(a) Copper and lead are recovered from certain silver ores and concentrates shipped to United States refineries. These metals are valued at the average prices for the year, namely: copper, 12.5 cents and lead 8.5 cents per pound in 1921.

(b) Nickel metal and metallic contents of all Nickel compounds.

(c) Cobalt metal and metallic contents of all Cobalt compounds.

(d) Prior to 1914 an estimate based on assays was made of the nickel, cobalt and arsenic contained in the ores; subsequently actual recoveries have been reported.

Since the discovery of silver at Cobalt in 1903 shipments from the camp and outlying silver areas have been as follows:

TABLE IX.—SILVER SHIPMENTS BY CAMPS

Year	Average price, cents per ounce (New York)	Silver Shipments in Troy Ounces, 1904-1921					
		Total Ounces	Cobalt	Casey Township	South Lorrain	Gowganda	Montreal River and Maple Mountain
1904	57.221	206,875	206,875				
1905	60.352	2,451,356	2,451,356				
1906	66.791	5,401,766	5,401,766				
1907	65.237	10,023,311	10,023,311				
1908	52.864	19,437,875	19,424,251	500	13,124		
1909	51.502	25,897,825	25,658,683	26,185	194,955		18,002
1910	53.486	30,645,181	29,849,981	92,544	221,133	471,688	9,835
1911	53.340	31,507,791	29,989,893	114,789	933,912	468,687	510
1912	60.835	30,243,859	28,605,940	253,824	834,119	549,976	
1913	57.791	29,681,975	28,105,505	825,108	248,992	502,370	
1914	54.811	25,162,841	24,155,699	499,643	108,199	399,300	
1915	49.684	24,746,534	24,280,366	223,939		242,229	
1916	65.661	19,915,090	19,008,517	445,900	77,280	383,393	
1917	81.417	19,401,893	18,327,258		10,000	1,064,635	
1918	96.772	17,661,694	16,807,407	143,901	72,188	638,198	
1919	111.122	11,214,317	10,314,689	171,278	4,586	723,764	
1920	100.900	10,845,436	10,402,249		8,253	433,352	1,582
1921	62.654	8,261,931	7,673,535	1,101	328,886	258,292	117
Total		322,707,550	310,687,281	2,942,613	3,055,627	6,135,884	30,046

Refineries.—The companies named hereunder with plants situated in southern Ontario, treat silver-cobalt ores, concentrates and residues:

REFINERS OF SILVER-COBALT ORES, 1921.

Name of Company.	Location of Works	P.O. Address
Deloro Smelting and Refining Co., Ltd.	Deloro	Deloro.
Coniagas Reduction Co., Limited.	Thorold	St. Catharines.
Ontario Smelters & Refiners, Ltd.	Welland	Welland.

The operations of the refining companies during 1921 are summarized in the figures given below. Apart from the silver recovered, from Cobalt and outlying silver areas, the marketed by-products had a value of \$1,056,596. Metallic cobalt was sold for \$3.00 per pound.

OPERATIONS OF SILVER-COBALT REFINERIES IN ONTARIO, 1921.

Schedule	Production	Marketed.	
	Quantity	Quantity	Value
			\$
Ore and Concentrates treated..... tons	2,047		
Residues treated..... "	2,984		
Silver..... fine ounces	3,709,693	3,884,683	2,668,107
Silver content of matte and residues..... ounces		245,679	172,309
Arsenic, white..... lbs.	3,509,921	2,982,525	233,763
Cobalt Oxide..... "	216,875	165,554	354,418
Cobalt content of residues, marketed..... "		55,826	49,724
Cobalt-nickel oxides, unseparated..... "		105,675	113,865
Cobalt, Metallic..... "	22,216	32,718	98,228
Nickel Oxide..... "	66,382	12,396	3,830
Nickel Sulphate and Hydrate..... "	5,503	5,503	393
Nickel, Metallic..... "	39,485	10,973	3,442
Copper content of matte and sulphate..... "		142,313	26,624
Total value of products marketed.....			3,724,703

The following figures have been compiled from information furnished by refineries in the United States which treated products from Ontario silver mines:—

	Quantity
Ore, Concentrates, etc., treated, tons.....	1,183
Silver recovered, ounces.....	562,160
Gold recovered, ounces.....	0.76
Copper recovered, lbs.....	63,042
Lead recovered, lbs.....	6,000

Shipments were consigned to the following:—

American Smelting and Refining Company, (Pueblo, Col., and Perth Amboy, N.J.).
 Pennsylvania Smelting Co., (Carnegie, Pa.).
 United States Metal Refining Co., (Chrome, N.J.).

Late in 1921 the new insecticide plant of the Deloro Smelting and Refining Company commenced operations, the principal products being arsenate of lime and arsenate of lead. The price of white arsenic (arsenious oxide) rose as high as 20 cents per pound in 1920 and fell as low as six cents in 1921. Arsenic is in demand, calcium arsenate particularly, as an antidote for the boll weevil in the cotton growing areas of the United States. Antimony was substituted for arsenic in glass manufacture during the war, owing to the latter being reserved for the manufacture of insecticides. Generally speaking, arsenic is preferred to antimony in the glass industry. In the Province the recovery of arsenic is entirely as a by-product in the treatment of silver-cobalt arsenides by southern Ontario refineries.

TABLE X.—DIVIDENDS AND BONUSES PAID BY SILVER MINING COMPANIES TO DECEMBER 31, 1921

Name of Company	Date of Incorporation	Authorized Capital	Capital Stock Issued	Par value per share	Dividends and Bonuses paid to end of 1920	Dividends and Bonuses paid during 1921	Total Dividends and Bonuses paid to 31st Dec., 1921	Date when last Dividend or Bonus was paid
Aladdin Cobalt Company, Limited.....	Aug. 23, 1912	\$ 500,000	\$ 500,000	\$ c. 5 00	\$ 75,000 00	\$ c.	\$ c. 75,000 00	April 30, 1917
Beaver Consolidated Mines, Ltd.	Mar. 1, 1907	2,000,000	2,000,000	1 00	710,000 00	.....	710,000 00	May 31, 1920
Buffalo Mines, Ltd., The (a).....	April 27, 1906	500,000	500,000	50	2,787,000 00	.....	2,787,000 00	May 28, 1914
Cassey Cobalt Silver Mining Co., Limited.....	Dec. 19, 1906	100,000	100,000	1 00	203,249 33	.....	203,249 33	Apr. 22, 1914
Cobalt Central Mines Co., Ltd.....	Dec. 13, 1905	5,000,000	5,000,000	1 00	192,845 00	.....	192,845 00	Aug. 25, 1909
Cobalt Comet Mines, Ltd. (b).....	April 16, 1913	1,000,000	1,000,000	1 00	230,000 00	.....	230,000 00	April 1, 1915
Cobalt Silver Queen, Ltd.....	April 1, 1906	1,500,000	1,500,000	1 00	315,000 00	.....	315,000 00	Dec. 31, 1908
Coniagas Mines, Limited, The.....	Nov. 24, 1906	4,000,000	4,000,000	5 00	10,740,000 00	200,000 00	10,940,000 00	Nov. 1, 1921
Crown Reserve Mining Co., Ltd.....	Jan. 16, 1907	2,000,000	1,999,957	1 00	6,190,849 00	.....	6,190,849 00	Dec. 28, 1916
Foster Cobalt Mining Co., Ltd.....	Feb. 14, 1906	1,000,000	915,588	1 00	45,000 00	.....	45,000 00	Jan. 1, 1907
Hudson Bay Mines, Ltd.....	July 16, 1909	3,500,000	3,200,050	5 00	778,909 42	.....	778,909 42	Aug. 31, 1913
Kerr Lake Mining Company, Ltd. (c).....	Aug. 9, 1905	40,000	40,000	100 00	8,865,000 00	610,000 00	9,475,000 00	Oct. 13, 1921
La Rose Mines, Ltd.....	May 31, 1908	1,500,000	1,500,000	1 00	7,505,409 56	.....	7,505,409 56	April 20, 1918
McKinley-Darragh-Savage Mines of Cobalt, Ltd.	April 27, 1906	2,500,000	2,247,692	1 00	5,955,391 86	.....	5,955,391 86	Oct. 1, 1920
Mining Corporation of Canada, Ltd.....	Nov. 23, 1916	8,300,250	8,300,250	5 00	5,498,874 97	.....	5,498,874 97	Sept. 15, 1920
City of Cobalt Mining Co., Ltd. (d).....	Oct. 5, 1906 Jan. 7, 1909	500,000 1,500,000	500,000 1,500,000	1 00	145,000 00	.....	145,000 00	April 15, 1920
Cobalt Lake Mining Co., Ltd. (d).....	Dec. 22, 1906	3,000,000	3,000,000	1 00	465,000 00	.....	465,000 00	May 29, 1914

TABLE X.—Continued.

Name of Company	Date of Incorporation	Authorized Capital	Capital Stock Issued	Par value per share	Dividends and Bonuses paid to end of 1920	Dividends and Bonuses paid during 1921	Total Dividends and Bonuses paid to 31st Dec., 1921	Date when last Dividend or Bonus was paid
Cobalt Townsite Mining Co., Ltd. (d).	May 8, 1906	\$ 100,000	\$ 45,011	\$ c. 1 00	\$ 1,042,259 61	\$ c.	\$ 1,042,259 61	Nov. 11, 1914
Nipissing Mining Co., Ltd. (e)	Dec. 16, 1904	250,000	250,000	100 00	23,118,297 25	1,175,000 00	24,293,297 25	Oct. 20, 1920
Penn-Canadian Mines, Ltd. (f)	April 24, 1912	1,500,000	1,349,705	1 00	175,461 65		175,461 65	Sept. 10, 1917
Peterson Lake Silver-Cobalt Mining Co., Ltd.	April 11, 1906	3,000,000	2,469,802	1 00	462,350 35		462,350 35	Jan. 2, 1917
Right of Way Mining Co., Ltd.	July 13, 1906	500,000	499,518	1 00	324,643 93		324,643 93	Oct. 1, 1909
Right of Way Mines, Ltd.	Sept. 11, 1909	2,000,000	1,685,500	1 00	252,825 00		252,825 00	Mar. 17, 1917
Seneca-Superior Silver Mines, Ltd.	Sept. 29, 1911	500,000	478,884	1 00	1,579,817 20		1,579,817 20	Dec. 15, 1916
Temiskaming Mining Co., Ltd.	Nov. 5, 1906	2,500,000	2,500,000	1 00	2,159,156 25		2,159,156 25	Jan. 31, 1920
Temiskaming and Hudson Bay Mining Co., Ltd.	July 10, 1903	25,000	7,761	1 00	1,940,250 00		1,940,250 00	Nov. 10, 1914
Trethewey Silver Cobalt Mines, Ltd.	May 30, 1906							
	June 1, 1911	2,000,000	1,000,000	1 00	1,211,998 50		1,211,998 50	Jan. 2, 1919
Wettlaufer Lorrain Silver Mines, Ltd.	Nov. 30, 1908	1,500,000	1,416,590	1 00	637,465 50		637,465 50	Sept. 22, 1913
Total					83,607,054 38	1,985,000 00	85,592,054 38	

(a) In 1917 the capital stock of the company was reduced from \$1,000,000 to \$750,000, in 1918 from \$750,000 to \$500,000, and on December 21, 1919, from \$500,000 to \$150,000, by returning to shareholders amounts equal to the reduction in capital, leaving 300,000 shares issued of 50 cents each. The mine was sold to the Mining Corporation of Canada, and operated by it in 1920 and subsequently.

(b) Cash assets amounting to \$50,000 paid on April 27, 1917.

(c) In addition a return of capital amounting to \$600,000 was made on July 3, 1919 to stockholders of the Kerr Lake Mines, Ltd.

(d) Mining Corporation of Canada, Limited, owns and operates the City of Cobalt, Cobalt Lake and Cobalt Townsite mines.

(e) Includes \$16,288,297 25 paid in dividends by the Nipissing Mines Co. (the holding company) to the end of 1916.

(f) Paid out of capital \$40,491.15 on Sept. 10, 1917, and an equal amount on April 24, 1918.

Nickel, Copper and the Platinum Metals

The nickel-copper industry, which developed gradually prior to the war and expanded greatly during that period, has been forced to greatly curtail operations or suspend them temporarily owing to the accumulated stocks of nickel and copper and lack of market for new production. If the disarmament programme is ratified the outlet for nickel in warship construction will be small. The present surplus stock will require time for absorption. A revival of the industry, therefore, depends on increased commercial activity and widened industrial uses for nickel and its alloys. Early in the year the British America Nickel Corporation closed down its mine, smelter and refinery, and was followed in September by the International Nickel Company of Canada. The Mond Nickel Company, which ships matte to its refinery in Wales, continued operations on a reduced scale throughout the year. The International Nickel Company is dismantling its refinery at Bayonne, New Jersey, and shipping part of the equipment to the refinery at Port Colborne, Ontario. Hereafter it is expected that the larger part of nickel-copper matte produced by this company will be treated in Canada at the Port Colborne refinery.

A few years ago engineers were confined to the use of steel, brass or bronze in the design and construction of plant and equipment, but research and experiment has changed this condition and now there are numerous alloys available, each with one or more outstanding properties which make it particularly desirable for special applications. The use of nickel has largely figured in these alloys and the one most widely used is the natural alloy called "Monel" metal, which is produced by the International Company directly from nickel-copper matte after the sulphur content has been eliminated. It is stronger than mild steel, retains its strength at high temperatures and has maximum resistance to corrosion and erosion. It resists crystallization and fatigue and will take a high nickel polish.

The production of ore during the year from the several mines was as follows:—

British America Nickel Corporation:—		Tons
Murray.....		45,366
International Nickel Company of Canada:—		
Creighton.....		54,471
Mond Nickel Company:—		
Levack, Garson, Worthington, Victoria No. 1 and Frood.....	157,317	
Bruce.....	5,439	
		162,756
Total.....		262,593

In Table XI, following, is indicated the course of the nickel industry during the last five years. That this metal takes on added importance during times of war is sufficiently shown by the fact that while in 1914 the quantity of ore smelted was 947,053 tons, it rose in 1918 to 1,559,892 tons, and fell again as noted in the table to 393,768 tons in 1921.

For the purpose of this table the nickel and copper in matte exported in 1921 were valued at 20 cents and 10 cents per pound, respectively.

TABLE XI.—NICKEL-COPPER MINING AND SMELTING, 1917-1921.

Schedule	1917	1918	1919	1920	1921
Ore raised..... tons	1,536,828	1,643,040	614,955	1,200,830	262,593
Ore smelted..... "	1,453,661	1,559,892	754,567	1,087,531	393,768
Bessemer matte produced..... "	78,897	87,184	42,735	57,938	19,498
Nickel contents of matte..... "	41,887	45,886	22,035	30,615	9,128
Copper contents of matte..... "	21,197	23,843	12,099	16,021	6,323
Matte exported*..... "			25,207	40,367	10,466
Matte refined in Canada..... "		5334	10,911	17,297	5,558
Men employed..... No.	3,356	3,145	2,536	3,258	1,895
Wages paid.....	\$5,570,587	7,861,773	3,382,154	5,555,469	1,557,696

*All matte was exported prior to 1918 when refining in Canada began at Port Colborne, Ontario.

The following figures summarize the operations of the International Nickel Company of Canada's refinery at Port Colborne and that of the British America Nickel Corporation at Deschênes on the Ottawa river:—

TABLE XII.—NICKEL-COPPER REFINING, 1921.

Schedule	Quantity	Value
		\$
Matte treated..... tons	5,558	
Nickel Oxide marketed..... lbs.	1,389,623	281,561
Metallic Nickel recovered..... "	5,419,174	1,821,917
Blisters Copper and Electrolytic Copper recovered..... "	2,926,407	330,084
Gold recovered*..... ounces	2,358	48,637
Silver recovered*..... "	49,515	30,953
Platinum metals recovered*..... "	13,418	862,034
Employees..... No.	454	
Wages paid.....		\$ 367,216

*Includes recoveries by the Mond Nickel Company at Clydach in Wales

Returns by refineries treating Ontario silver ores show a recovery of 205,355 pounds of copper. In addition 10,973 pounds of nickel and 12,396 pounds of nickel oxide were marketed.

The average New York price of electrolytic copper was 12.502 cents per pound for the full year, as compared with 17.456 cents in 1920.

Platinum Metals.—Ontario nickel-copper ores of the Sudbury area contain the precious metals, gold, silver and metals of the platinum group. The latter may be divided into two main sub-groups on a specific gravity basis as follows:

Metal	Specific Gravity	Metal	Specific Gravity
Palladium (Pd.).....	12.16	Platinum (Pt.).....	21.40
Rhodium (Rh.).....	12.44	Iridium (Ir.).....	21.42
Ruthenium (Ru.).....	12.10	Osmium (Os.).....	22.50

In the last annual report figures were given for 1920 showing platinum metals produced in Canada, United States and Great Britain from the refining of Ontario nickel-copper matte. Complete figures for 1921 are given on next page.

Precious metals cement was shipped by the International Nickel Company of Canada to the United States for further refining along with similar recoveries made at the Bayonne, N.J., plant.

Production of platinum metals by the British America (reporting for the first time), International and Mond companies follows:—

	Platinum	Palladium	[*] Iridium, etc.	Total
Quantity Troy ounces	5,412	7,729	277	13,418
Value \$	402,508	446,588	12,938	862,034

*Iridium and rhodium in small amounts was grouped by the Mond Company with gold and is not recorded in the above figures.

At the Bayonne plant 2,217 tons of matte were treated, although the matte bears little relation to precious metals recovered as the residues treated accumulate over irregular periods. In the figures above given platinum metals contained in precious metals cement shipped from Port Colborne to the refinery of the International Nickel Company, at Bayonne, N.J., are included with recoveries from the matte treated in the United States.

Average prices as reported by the U.S. Geological Survey were platinum \$75 per ounce troy, palladium \$59, iridium \$86 (containing five per cent. platinum.)

Iron Ore

The only iron ore raised in 1921 was 42,198 tons of siderite from the Magpie mine of the Algoma Steel Corporation. Total shipments of ore and briquettes from the three properties noted below were 58,499 tons worth \$227,134. Of the total shipments only 100 tons worth \$459 were consigned to points other than Ontario blast furnaces. These consisted of 78 tons of briquettes by Moose Mountain, Limited, and a trial shipment of 22 tons of hematite from the Wallbridge mine, near Madoc. From the Magpie mine, which closed down in March, the Algoma Steel Corporation of Sault Ste. Marie, received 58,399 tons of roasted siderite.

During the year repairs to the blast furnace at Port Arthur were made with a view to placing it in operation again to handle ore from a property near the Ontario-Minnesota boundary, which is being developed by the Palatine Mining Company. Some work was done at Atikokan, 142 miles west of Port Arthur, to more fully determine the quality and extent of certain ore bodies.

Following is a list of iron mines from which shipments were made during the year:

SHIPPERS OF IRON ORE, 1921.

Company or Firm.	Mine.	Location.	Kind of Ore.	P.O. Address of Company.
Algoma Steel Corporation, Limited	Magpie	Algoma dist.	Siderite	Sault Ste. Marie.
Moose Mountain, Ltd.	Moose Mount'n	Hutton tp. (Sudbury dist.)	Magnetite	Sellwood.
Wallbridge, Mrs. T. C.	Wallbridge	Madoc tp.	Hematite	Madoc.

Pig Iron, Steel and Ferro-Alloys

The iron and steel industry experienced depression throughout the greater part of the year. Prices returned practically to pre-war levels. Blast furnaces were operated for different periods by the Algoma Steel Corporation, Steel Company of Canada, Canadian Furnace Company and the Midland Iron and Steel Company. In Table I Ontario is credited with the proportional output from domestic ore, or 13.4 per cent. of the total pig iron made.

The average Valley quotation for the year was \$21.71 per gross ton for basic pig iron. In the *Iron Age*, issue of December 8, 1921, the cost per gross ton (2,240 pounds) of producing pig iron in the three principal iron centres of the United States was given as follows: Pittsburgh, \$19.29; Chicago, \$19.54 and Birmingham, \$15.58.

The Algoma Steel Corporation produced 9,750 tons of spiegel valued at \$436,559. Electro-metals, Limited, of Welland, produced 12,209 gross tons of ferro-silicon valued at \$561,720. For this output of several grades ranging from 15 to 80 per cent. ferro the following raw materials were used; 370 gross tons of pyrite cinder from the United States; 1,315 tons of steel turnings and 12,083 tons of Killarney quartzite containing 99 per cent. silica.

BLAST FURNACES IN ONTARIO FOR THE PRODUCTION OF PIG IRON.

Company	Location	Furnaces		Remarks
		No.	Daily capacity, gross tons	
Algoma Steel Corporation, Ltd....	Sault Ste. Marie..	4	1,450	Active.
Atikokan Iron Company.....	Port Arthur.....	1	175	Idle since 1911.
Canadian Furnace Co., Ltd.....	Port Colborne....	1	325	Active.
Canadian Steel Corporation, Ltd..	Ojibway (near Windsor).....	2	1,100	Under construction.
Midland Iron and Steel Co., Ltd..	Midland.....	1	120	Idle since Feb., 1921.
Parry Sound Iron Co., Ltd.....	Parry Sound.....	1	90	Idle since Oct. 1., 1919.
Standard Iron Co., Ltd.....	Deseronto.....	1	60	Idle since June 9, 1919.
Steel Company of Canada, Ltd....	Hamilton.....	2	750	Active.

Note.—The first and last mentioned produce open-hearth steel as well as pig iron.

IRON BLAST FURNACES IN OPERATION, 1921.

Name of Company	Furnaces		Fuel used.	Location.
	Number.	Ave. days operated.		
Algoma Steel Corporation, Ltd....	4	358	Coke.....	Sault Ste. Marie.
Canadian Furnace Company, Ltd..	1	114	Coke.....	Port Colborne.
Midland Iron and Steel Co., Ltd..	1	41	Coke.....	Midland.
Steel Company of Canada, Ltd....	2	365	Coke, coal and gas.....	Hamilton.

The following table gives particulars of the iron and steel-making industry of the Province for the last five years:—

TABLE XIII.—IRON AND STEEL STATISTICS, 1917-1921.

Schedule.	1917	1918	1919	1920	1921
Ontario ore smelted..... short tons	94,318	99,852	97,514	152,176	126,653
Foreign ore smelted..... "	1,221,881	1,400,085	1,201,834	1,341,661	818,749
Limestone for flux..... "	319,535	405,683	343,907	349,960	221,761
Coke..... "	723,657	869,729	736,872	818,698	420,358
Charcoal..... bush.	1,288,390		177,795		
Pig iron produced..... short tons	691,233	751,650	623,586	748,173	494,901
Value of pig iron produced..... \$	14,201,695	20,522,356	16,010,537	21,652,308	11,856,352
Steel made..... short tons	862,504	881,509	616,251	707,692	932,473
Value of Steel made..... \$	22,179,982	28,792,361	17,913,263	26,366,524	15,861,635

Lead

The only producing lead mine in Ontario is that of the Kingdon Mining, Smelting and Manufacturing Company, Ltd., which also operates a smelter at Galetta, on the Ottawa river. With the exception of a small recovery of lead in United States refineries from Ontario silver ores, the total sales of 3,576,222 pounds worth \$191,113 were shipped from Galetta. During the year 33,557 tons of ore were mined and concentrated. Shipments of pig lead were made to Canadian points. The average New York price for the year was 4.545 cents per pound, the lowest since 1914. Prices at Montreal, the main Canadian market, are generally higher than in the United States, the Montreal average price being 5.742 cents per pound in 1921 and the Toronto price 5.849 cents.

About 1,500 tons of lead slag, a residue from the Newnan hearth, was on hand at Galetta at the end of the year. A small grab sample assayed 40 per cent. lead and 10 per cent. zinc; and a similar flue dust sample gave 70 per cent. lead and three per cent. zinc. The erection of a small blast furnace is under consideration for further treating slag and flue dust. Zinc blende is recovered from concentrating tables and bagged for future use. A description of mine and smelter appeared in the *Canadian Mining Journal*, issue of February 24, 1922.

NON-METALLIC MINERALS

Actinolite

Shipments during the year were seventy-eight tons, valued at \$915. There is only one producer in the Province, namely, the Actinolite Mining Company, with a mill at the village of the same name, situated about four miles north of Tweed station on the Canadian Pacific railway. The mineral is mined in the townships of Kaladar and Elzevir, Hastings county, and the head office of the company is Bloomfield, New Jersey. The product, which is fibrous in nature, is used principally for roofing purposes, as an ingredient in coal-tar compounds.

Barite (Barytes)

There was a production by H. C. Bellew of 6 Saint Sacrament St., Montreal, Que., of approximately 200 tons of barite or heavy spar. No shipments were made from the deposit, which is located on lot 20, concession X, township of North Burgess, Lanark county.

Calcite and Dolomite

There is a growing market for ground calcite and dolomite in the paint and other trades. From Palmerston township in Frontenac county, T. B. Caldwell, of Perth, shipped seventy tons of pure calcite to paint manufacturers, for experimental use.

A dolomite deposit was opened up at Baptiste lake, Herschel township, by the Ontario Dolomite Manufacturing Company, Ltd. No shipments to the Toronto grinding plant of the company were made in 1921. This mineral is coming into use for the manufacture of artificial stone.

Corundum

The entire production of this natural abrasive, 403 tons, valued at \$55,965, was the output of Corundum, Limited, operating at Craigmont. During the year 11,256 tons of tailings from lot 4, concession XVIII, Raglan township, were milled. Shipments were made in "grain" form. Artificial abrasives are replacing corundum for many purposes.

Feldspar

For several years prior to 1920, Ontario's output of feldspar ranged from 12,000 to 20,000 tons per annum. In 1920 shipments jumped to 37,335 tons, worth \$268,295, due to an increased demand by United States pottery and porcelain manufacturers. In the second half of 1921, shipments fell off, particularly those of second-grade spar. Prices dropped during the year from \$9.00 per ton f.o.b. cars to \$7.00 for No. 1 spar and from \$6.00 to \$5.00 per ton for No. 2. The bulk of the supply is quarried in Frontenac and Hastings counties. Shipments go chiefly to the pottery and porcelain centres of New Jersey and Ohio. The Feldspar Milling Company of Toronto, with plant on Don Esplanade, has a grinding capacity of about 6,000 tons per annum. The new plant of the

Frontenac Floor and Wall Tile Co., completed in December, is capable of handling 1,500 tons per year, and can be doubled by adding another pebble mill. About 2,250 tons were ground in Ontario in 1921 by the Toronto firm. Total shipments in 1921 were 19,887 tons, worth \$170,133, which includes both crude and ground spar.

There is a growing demand for pink spar, crushed to pass one-quarter inch mesh and retained on one-eighth inch mesh, for use as a "stucco dash." Second-grade spar, including chips, may be marketed in this form.

Shippers in 1921 are noted hereunder:

FELDSPAR SHIPPERS, 1921.

Name.	Location of Deposit.	P.O. Address.
Canadian Non-Metallic Minerals, Ltd.	Dickens tp.	207 James St., Montreal.
Dillon and Mills.	Lot 23, Con. VI, Monteaale tp.	Hybla.
Eureka Flint and Spar Co.	Lot 16, Con. XI, Portland tp.	Verona and Trenton, N.J.
Federal Feldspar, Ltd.	Lot 25, Con. III, Bedford tp.	46 Elgin St., Ottawa.
Feldspar Quarries, Ltd.	Portland tp.	60 Front St. E., Toronto.
Feldspars, Limited.	Richardson Mine, Bedford tp.	103 Bay St., Toronto.
Gardner Feldspar Co.	Lots 1 and 2, Con. XI, Loughborough tp.	Hartington.
Industrial Minerals Corp. of Canada, Ltd.	Lots 29 and 30, Con. XV, Monmouth tp.	805 Bank of Hamilton Bldg., Toronto.
International Feldspar Co., Ltd.	Lot 2, Con. III, Bedford tp.	214 Humber Bldg., Highland Park, Detroit, Mich.
McConnell Consolidated Mines, Ltd.	Lot 3, Con. VIII, Bathurst tp. (Kirkham quarry)	Perth, Ont.
North American Feldspar, Ltd.	Pickins mine, Gooderham.	24 Orchard Park Rd., Toronto.
O'Brien and Fowler.	Lots 5 and 8, Cons. II and III, March tp.	17 Beech St., Ottawa.
Orser-Kraft Feldspar, Ltd.	S. Sherbrooke, Bathurst and Drummond tps.	Box 366, Perth.
Orser and Wilson.	Lot 11, Con. IX, Loughborough tp.	Perth, Ont.
Provincial Feldspar Co.	Lot 15, Con. VI, S. Sherbrooke.	33 Richmond St. W., Toronto.
Rock Products Company, The.	Lot 10, Con. VI, Bathurst tp. (Jas. Keays' quarry).	1154 Nicholas Bldg., Toledo, Ohio.
Storrington Feldspar Company, Ltd.	Lots 8, 9, 10, Con. XIII, Storrington.	C. G. Walton, Sec.-Treas., Elgin.
Verona Mining Co.	Lots 18, 19 and pt. 20, Con. VII, Monteaale.	Hybla and 404 Harrison Bldg., Philadelphia, Pa.

Fluorspar

The output of this mineral declined from 3,704 tons in 1920 to 115 tons, worth \$1,744, in 1921. Curtailed operations in the steel industry was the primary cause of this situation. The maximum output was in 1918, when 7,286 tons were marketed.

There were only two shippers in 1921, as follows:

FLUORSPAR SHIPPERS, 1921.

Name.	Location.	Address.
Cross and Wellington.....	Lot 11, Con. XIII, Huntingdon	Madoc.
Herrington and Herrington....	Lot 2, Con. XII, Madoc.....	Madoc.

Graphite

The graphite industry was stagnant during the year, only one operator, the Black Donald Graphite Company, reporting shipments. The Timmins Graphite Mines treated a small quantity of crude ore, and the two companies had on hand at the end of the year 614 tons of unsold product. Shipments by the Black Donald Company were 21½ tons of flake and 341½ tons of dust, or a total of 363 tons, valued at \$23,273.

GRAPHITE OPERATORS, 1921.

Company.	Location of Mine.	P.O. Address.
Black Donald Graphite Co., Ltd. Timmins Graphite Mines, The.	Brougham tp., Renfrew county N. Burgess tp., Lanark county	Calabogie. Stanleyville.

Artificial graphite, a product of the electric furnace, is manufactured by the Acheson Graphite Company of Niagara Falls, Ontario. The output in 1921 was 376,508 pounds.

Gypsum

The Ontario Gypsum Company is the only operating Company in the Province, with mines and mills at Caledonia and Lythmore, in Seneca and Oneida townships, Haldimand county, and head office at Paris. When the Crown Gypsum Company's mill at Lythmore was purchased, a new mine at Lythmore, about five miles east of Hagersville on the Michigan Central railway, was opened up and the old Martindale mine abandoned. The company mines, crushes, grinds and calcines gypsum; manufactures wall plaster, plaster of Paris and other gypsum products. Crushed and fine-ground gypsum marketed in 1921, totalled 37,751 tons, calcined gypsum 15,020 and calcined gypsum used in manufactured products, 32,019 tons; a total of 84,765 tons, valued at \$433,053. Gypsum products, including wall board and fireproof blocks, are finding an increasing market in the building industry.

The Emley patented process of manufacturing plastic gypsum has been adopted by this company in the Caledonia mill, and similar machinery is being installed at Lythmore. In the new process plaster of Paris is ground in a ball

mill, thereby driving out the moisture of crystallization. Recombining while still in the mill has the effect of making hardwall plaster denser and more plastic, giving it the property of easier spreading and making it capable of carrying more sand. This process is being introduced rapidly in the United States, and means a general improvement in the plaster industry. The Ontario Gypsum Company was the first company in Canada to adopt the Emley process, patented by W. E. Emley, of the United States Bureau of Standards, Washington, D.C.

Iron Pyrites

The iron pyrites or sulphur ore industry in Ontario, in 1921, reflects the general economic depression, and the outlook for this mineral is not bright. There were mined during the year a total of 26,107 tons, of which 19,375 tons, worth \$91,604, were shipped. A final clean up of the Wawa (Helen mine) stock pile was made by the Algoma Steel Corporation and the ore shipped to Sault Ste. Marie. Ontario shipments contained thirty-eight per cent. sulphur, with the exception of the sulphide deposit of the Nichols Chemical Company, which assayed 33.6 per cent. sulphur.

Native sulphur from the "Gulf" states of Texas and Louisiana, made available more cheaply than pyrites could be, is supplanting the latter on the North American continent. It also finds sale on the European market in competition with Sicilian sulphur. The only place where Spanish pyrites competes successfully on the United States market is on the Atlantic seaboard, and less than one quarter of the pre-war quantity of iron pyrites is being imported into the United States. In fact, domestic production of iron pyrites in the United States meets its chief competition from American native sulphur, rather than from imported pyrites.

Following is a list of pyrite shippers in 1921:

IRON PYRITES SHIPPERS, 1921.

Name of Owner, Firm or Company.	Location or Name of Mine.	P.O. Address of Manager, etc.
Algoma Steel Corporation, Limited.....	Helen.....	Sault Ste. Marie.
Grasselli Chemical Co.....	Caldwell.....	Flower Station.
Nichols Chemical Co., Limited, The....	Sulphide.....	Sulphide.
	Vermillion Lake.....	Northpines.

Mica

The industry, which is centred in Eastern Ontario, was inactive during most of the year. Shipments totalled 218 tons, including 86 tons of scrap mica. The total value of all grades was \$28,891, as compared with \$54,169 in 1920, when 719 tons were marketed. Scrap mica is now being concentrated and ground to various degrees of fineness for a wide variety of uses, including the rubber trade, but principally for the manufacture of prepared roofing materials.

The Loughborough Mining Company, operating the Lacey mine at Sydenham, Frontenac county, was the largest shipper of rough-cobbed mica.

Prices for thumb-trimmed mica, depending on quality, ranged as follows:

Size.	Price per lb.	Size.	Price per lb.
1" x 1"	7c. to 17c.	2" x 4"	60c. to 80c.
1" x 2"	13c. to 17c.	3" x 5"	\$1.35 to \$1.50
1" x 3"	20c. to 35c.	4" x 6"	\$2.00 to \$2.25
2" x 3"	40c. to 60c.		

Following is a list of mica shippers:

MICA SHIPPERS, 1921.

Name of Owner or Producer.	Location or Name of Mine.	P.O. Address of Manager, etc.
Elliott, Wm. M.	Mica lake, Butt tp.	3433 Walnut St., Chicago, Ill.
Green, George.	Bedford tp.	Perth Road.
Kent Bros. and Estate J. M. Stoness.	Bedford tp.	Kingston.
Kingston and Perth Mining Co.	North Burgess tp.	Kingston.
Loughborough Mining Co., Ltd.	Loughborough tp.	Sydenham.
McLaren, W. L.	North Burgess tp.	Perth.
Trousdale, Jas.		Sydenham.

Mineral Waters

Statistics of production and valuation are not entirely satisfactory, for the reason that in many cases mineral waters are shipped from the springs in barrels or other containers to bottling works, and only a nominal valuation is given for such shipments. In other cases a much higher valuation is placed on the product where bottling works are located at the springs. The record does not include consumption of mineral waters for medicinal or bathing uses in connection with sanitarium, such as those located at St. Catharines and Preston Springs. Shipments reported were 308,647 Imperial gallons, valued at \$14,438.

Below are tabulated records of shipments since reports were first received in 1918:

	1918	1919	1920	1921
Imperial gallons.	208,498	276,833	127,150	308,647
Value.	\$133,808	\$19,290	\$15,059	\$14,438

Natural Gas

A complete discussion, "Natural Gas in 1921," by R. B. Harkness, Natural Gas Commissioner, appears as Part V, Volume XXXI, Report of the Ontario

Department of Mines. Production was 8,532,234,000 cubic feet, valued by the producers at \$2,975,502. The average retail price in 1921 was about 45 cents per M. cubic feet.

Peat

Shipments for the year from the Alfred bog, east of Ottawa, where experimental operations are being carried on jointly by the Ontario and Federal governments, were 1,666 tons, valued at \$7,800. About 4,000 tons were manufactured, but all fuel not sold was lost in November, by a fire which destroyed the storage pile.

The work carried on at Alfred is primarily an investigation with the object of developing a type of machinery suitable for peat fuel manufacture by the air-drying method. In 1921 the plant was in operation for 107 days, or about the average period feasible in our climate. For fuller description of the plant see progress statement of the Joint Peat Committee, issued as Part IV, Volume XXXI, Report of the Ontario Department of Mines.

Petroleum

A report on "Petroleum in 1921," by the Natural Gas Commissioner, appears in Vol. XXXI, Part V. The following statistical tables, which are repeated here for convenience, are taken from the above-mentioned report.

CRUDE PETROLEUM PRODUCTION (1); BY FIELDS, 1917-1921.

Field.	1917	1918	1919	1920	1921
	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.
Petrolia and Enniskillen.....	74,267	65,467	70,087	65,082	68,484
Oil Springs.....	43,902	44,671	45,245	39,388	40,967
Moore township.....	6,282	6,367	4,029	7,036	7,536
Sarnia township.....	4,494	3,438	4,259	3,495	4,068
Plympton township.....	579	412	560	531	481
Bothwell.....	29,682	29,116	29,425	25,563	26,877
Dover, West } Tilbury.....	10,041	25,228	16,705	12,171	7,473
Tilbury, East }			1,660	623	1,003
Raleigh township.....				(2)	3,320
Dutton.....	2,941	1,875	1,272	837	
Onondaga township.....	383	1,186	197	341	566
Belle River.....		447			
Mosa township.....	20,999	108,988	45,860	24,063	10,764
Thamesville.....	6,420	1,565	801	1,131	1,320
Total Production..... Bbls.	202,990	288,760	220,100	181,750	172,859
Value..... \$	475,000	781,097	632,789	724,145	466,716
Average price per Bbl. (3)..... \$	2.34	2.70½	2.87½	3.98½	2.68½

(1) Figures supplied by J. C. Waddell, Supervisor of Petroleum Bounties, Petrolia.

(2) Production for 1920 in Raleigh township was included with that of Dover West.

(3) A bounty of 52½ cents per barrel (35 Imperial gallons), or a total of \$90,748.78, was paid in addition by the Federal Government under The "Petroleum Bounty Act."

Four refineries operated in the Province in 1921, as noted hereunder:

PETROLEUM REFINERIES, 1921.

Company.	Location of Refinery.	Days Operated	Head Office Address.
British American Oil Co., Ltd.	Toronto, Cherry St. . . .	314	Toronto, Royal Bank Bldg.
Canadian Oil Companies, Limited.	Petrolia.	309	Toronto, Excelsior Life Bldg.
†Cities Service Oil Co., Ltd.	Wallaceburg.	306	Wallaceburg.
Imperial Oil, Limited.	Sarnia.	312	Sarnia.

†This company took over the Great Lakes Oil Company's refinery on Mar. 1, 1921.

The following table, summarized from annual reports of the Ontario Department of Mines for the years 1907-1920 and table supplied by the Dominion Bureau of Statistics for 1921, shows refinery operations for the past five years:

CRUDE PETROLEUM AND REFINERY STATISTICS, 1917-1921.

Schedule.	1917	1918	1919	1920	1921
Crude petroleum production					
Imp. gals.	7,107,700	10,106,615	7,703,515	6,361,234	6,050,062
Value " \$	475,000	781,097	632,789	724,145	559,198
American Crude, distilled,					
Imp. gals.	122,436,923	137,065,788	141,157,309	148,540,511	150,692,113
Value " \$	9,236,033	12,612,882	12,486,174	20,102,784	14,537,339
Canadian Crude, distilled,					
Imp. gals.	8,122,063	9,513,222	7,693,385	6,402,118	5,880,086
Value " \$	559,435	781,703	661,927	769,775	500,418
Per cent. of total.	6.22	6.49	5.17	4.13	3.75
Products:					
Illuminating oil. . . Imp. gals.	40,195,774	36,211,715	34,800,233	33,897,891	29,774,134
Value " \$	3,457,817	4,239,816	5,073,647	6,331,706	3,335,200
Lubricating oil. . . Imp. gals.	12,288,466	12,595,305	12,501,385	13,804,074	13,848,721
Value " \$	1,586,270	2,118,002	2,293,640	3,276,569	2,351,975
Benzine, Naphtha,					
Gasoline. Imp. gals.	34,611,056	39,156,447	44,625,590	47,418,420	51,033,337
Value " \$	8,292,828	10,244,328	11,677,077	14,485,935	12,655,244
Gas and Fuel oil, Tar,					
Imp. gals.	39,815,106	40,949,358	40,581,499	45,025,050	44,364,794
Value " \$	2,671,414	2,943,503	2,265,457	5,486,636	2,130,685
Paraffin Wax and Candles,					
lbs.	12,649,553	13,650,128	10,903,202	10,398,127	10,777,994
Value " \$	908,996	1,148,726	1,044,798	973,805	310,267
Employees. Ave. No.	1,289	1,312	1,580	1,736	1,560
Wages paid. \$	1,259,344	1,486,677	2,045,072	2,695,507	2,176,700

1 The value includes bounty paid to producers.

2 Figures for 1921 do not include Tar product, which was 18,971,400 pounds, with selling value of \$142,285.00.

Quartz and Silica Brick

Production for the year was 72,668 tons, valued at \$220,806. Quartz or silica is used in the smelting of nickel-copper ores in the Sudbury area, in the manufacture of ferro-silicon, for making silica brick and other uses requiring smaller quantities. The nickel companies supply their own requirements. Feldspar producers frequently recover quartz, which, if sufficiently pure, is shipped as a by-product. The Algoma Steel Corporation manufactured 1,094,069 silica brick during the year, using the same for lining blast furnaces.

The following operated quarries and made shipments in 1921:

QUARTZ SHIPPERS, 1921.

Name of Owner, Firm or Company.	P.O. Address of Operator.	Location of Quarry.
Algoma Steel Corporation.....	Sault Ste. Marie.....	A. C. Ry. (Deroche tp.).
Eureka Flint and Spar Company.....	Verona.....	Portland tp.
International Nickel Co. of Canada.....	Copper Cliff.....	Dill tp.
Mond Nickel Company.....	Coniston.....	Neelon tp.
Orser-Kraft Feldspar Company.....	Perth.....	Bathurst, Drummond and S. Sherbrooke tps.

Salt

Production of salt was well maintained in 1921, but brine for chemical plants was not as extensively used as in 1920. The ten salt plants operated are all situated in the south-western peninsula of the Province, between Kincardine on Lake Huron and Amherstburg on the Detroit river. Brine with salt equivalent of 50,529 tons was used in the chemical plant of Brunner Mond, Canada, Limited, at Amherstburg, and that of the Canadian Salt Company, Limited, at Sandwich. Chemicals produced include soda ash by the former company, while the latter turns out caustic soda and bleaching powder.

The following tables gives details of Ontario's salt industry over a five-year period:

SALT STATISTICS, 1917-1921.

Schedule.	1917	1918	1919	1920	1921
Land.....tons.	2,093	2,041	1,720	2,054	2,599
Coarse....."	32,236	25,232	35,150	28,709	28,925
Fine....."	56,028	53,908	47,571	39,663	36,074
Table and Dairy....."	34,251	34,324	34,396	42,474	40,931
Pressed Blocks....."					2,966
Brine (salt equivalent)....."	14,301	16,221	20,275	93,712	50,529
Total Sold or Used....."	138,909	131,726	148,112	206,612	161,024
Value of.....\$	1,047,707	1,287,039	1,395,368	1,544,867	1,643,527
Employees*.....No.	238	312	296	338	264
Wages.....\$	234,925	275,842	319,463	442,004	311,205

*Employees of chemical works are not included.

The list of companies producing brine or salt in 1921 was as follows:

SALT COMPANIES, 1921.

Name of Owner, Firm or Company.	Location of Wells or Works.	P.O. Address of Manager, etc.
Brunner, Mond Canada, Limited.....	Amherstburg*	Amherstburg.
Canadian Salt Company, Limited, The	Windsor.....	Windsor.
Dominion Salt Company, Limited, The	Sandwich*.....	Sarnia.
Elarton Salt Works Co., L'd.....	Sarnia.....	Watford, R.R. No. 5.
Exeter Salt Works Company, Limited	Warwick.....	Exeter.
Goderich Salt Co., Limited.....	Exeter.....	Goderich.
Ontario People's Salt and Soda Co., Ltd.	Goderich.....	Kincardine.
Western Canada Flour Mills Co., Ltd.	Kincardine.....	Goderich.
Western Salt Company, Limited.....	Goderich.....	Courtright.
Wingham Salt Works (Young Estate)...	Courtright.....	Wingham.
	Wingham.....	

*Chemical works using salt brine as raw material.

Talc and Soapstone

Shipments of crude and ground talc fell off from 21,411 tons, valued at \$162,784, in 1920, to 9,967 tons, worth \$140,390, in 1921. There was a larger proportion of ground talc sold than in 1920, as the valuation figures indicate. The American Talc Corporation early in the year turned over its mill and the Connolly mine to the Asbestos Pulp Company, Limited. The latter Company operated to September 1st, when the plant was shut down. The Henderson mine, an adjacent property, delivered its entire output of 7,916 tons of crude talc to the mill of Geo. H. Gillespie and Company, Limited. Ground talc prices ranged from \$8.00 to \$22.00 per ton, depending on grade. The entire industry is centred at Madoc in Hastings county.

The United States is the largest talc-producing country. Uses of ground talc in 1921, in order of consumption, as reported by the United States Geological Survey, were as follows: paper, 38 per cent.; paint, 23; roofing, 18; rubber, 9½; textile, 4; toilet powder, 2½; other uses, 5 per cent.

A deposit of soapstone has been located near Wabigoon station, District of Kenora. It closely resembles the Alberene stone of Virginia in mineral composition. There is no record to date of soapstone of domestic origin having been used in a commercial way in this Province.

TALC STATISTICS, 1917-1921

Schedule	1917	1918	1919	1920	1921
Crude talc shipped tons.	2,398	1,044	1,644	5,228	9,967
Ground talc shipped "	13,678	16,421	15,927	15,131	
Total value shipment \$	179,554	246,691	240,339	306,319	140,390
Employees, mine and mill No.	56	43	87	60	30
Wages paid \$	49,734	41,936	76,384	77,818	41,978

The following companies and firms were engaged in the mining and milling of tale during 1921:

TALC OPERATORS, 1921

Firm or Company	Location of Mine or Works	Address of Manager, etc.
*Henderson Mines, Limited.....	Huntingdon tp.....	Madoc.
Geo. H. Gillespie and Company, Ltd....	Madoc (grinding mill)....	Madoc.

*The Henderson mine was operated under lease by Henderson Mines, Limited, the product going to the mill of Geo. H. Gillespie and Company.

STRUCTURAL MATERIALS

During 1921 wholesale prices of commodities in general declined 21 per cent. from those obtaining at the close of 1920, or a total decline of nearly 46 per cent. from the peak of May, 1920. This unprecedented fall in prices, both as to swift-ness and severity, naturally had a depressing effect on general business. The first seven months of the year were marked by the greatest decline, while December recorded a reaction as shown by a small advance in general commodity prices.

Building construction naturally responded to the decline in prices of materials, but still there was hesitation to launch large building programmes in the fear that the downward trend might continue. On the other hand it was necessary to commence work on projects that had been long delayed by high construction costs, both as to materials and labour, which prevailed throughout the greater part of 1920. Building permits in 25 Ontario cities as reported by the *Labour Gazette* totalled \$49,276,999 in 1921, as compared with \$51,783,660 in 1920.

Clay Products

Many of the smaller and less-efficient clay-working plants which closed down during the war may not reopen, as the present-day tendency is towards larger and better-equipped plants. The Canadian National Clay Products Association is doing much in the way of standardization and towards improving conditions in the industry. The average price of common brick was \$7.96 per M in 1915, \$13.92 in 1919, \$17.74 in 1920 and \$17.68 in 1921. A decrease in fuel and labour costs permitted a small reduction in brick prices.

SEWER PIPE AND POTTERY WORKS, 1921.

Name of Company	Location of Plant and P.O. Address of Manager, etc.
SEWER PIPE.	
Dominion Sewer Pipe and Clay Industries, Ltd.....	Swansea.
Hamilton & Toronto Sewer Pipe Co., Ltd.....	Hamilton.
Ontario Sewer Pipe & Clay Products, Ltd.....	Mimico.
POTTERY.	
R. Campbell's Sons.....	100 Locke St. South, Hamilton.
Davis & Son, John.....	601 Merton St., Toronto.
Foster Pottery Company.....	Main St. West., Hamilton.

The table which follows gives the value of clay products marketed for the last pre-war year and subsequently:

VALUE OF CLAY PRODUCTS SOLD OR USED, 1913-21

Year	Brick		Pottery	Drain Tile	Sewer Pipe	Total
	Common	Pressed Fancy, Building Tile, etc.				
	\$	\$	\$	\$	\$	\$
1913.	3,283,894	1,162,860	52,875	292,767	600,297	5,392,693
1914.	2,336,207	894,381	25,720	277,530	571,750	4,165,597
1915.	763,591	375,865	49,387	321,253	361,283	1,871,379
1916.	509,559	495,895	87,025	275,471	216,749	1,584,699
1917.	713,824	776,302	94,501	546,040	379,923	2,509,590
1918.	665,454	592,286	88,275	309,899	362,536	2,018,450
1919.	1,966,711	726,500	119,551	354,700	609,100	3,776,562
1920.	2,209,265	1,178,656	127,049	359,373	860,811	4,735,154
1921.	2,025,643	2,059,606	69,984	397,104	939,463	5,094,696

Following is a list of 106 brick and tile operators who reported an output in 1921:—

BRICK AND TILE PLANTS, 1921.

Name.	Address.	Product.
Atlas Brick Co., Ltd.	Toronto, 30 Toronto St.	Pressed Brick.
Alvinston Brick and Tile Co., Ltd.	Alvinston.	Common Brick, Hollow Blocks and Tile.
Baird & Son, H. C.	Parkhill.	Brick and Tile.
Baker, Geo. C.	Arnprior.	Brick and Tile.
Bannerman, Geo., Jr.	Greenock, R.R. No. 1.	Common Brick and Tile.
Barnhardt, W. H.	Stratford.	Brick and Tile.
Bechtel, B. E.	Waterloo.	Brick.
Bennett, Robert.	Dunnville, Box 21.	Brick and Tile.
Booth Brick and Lumber Co., Ltd.	New Toronto.	Pressed Brick.
Brampton Pressed Brick Co.	Brampton.	Pressed Brick and Tile.
Broadwell & Son, B.	Kingsville.	Tile, Brick and Blocks.
Browncombe, H.	Cargill.	Brick and Tile.
Buck, J. L.	Port Rowan.	Brick, Tile and Blocks.
Canadian General Electric Co., Ltd.	Toronto, King St., W.	Pottery.
Canadian Pressed Brick Co., Ltd.	Hamilton, 36 Sun Life Building.	Pressed Brick.
Chapman, John.	Napanee.	Brick and Tile.
Cheeseman, Peter.	Hamilton, 670 King St., W.	Brick.
Cooksville Shale Brick Co., Ltd.	Toronto, 26 Queen St., E.	Brick.
Cooper, W. H.	Hamilton, 104 Clyde Block	Brick.
Crang, Jethro.	Toronto, 2 Regal Rd.	Brick.
Crawford Bros.	Hamilton, King and Mack- lin Sts.	Brick.
Curtin, Frank.	Lindsay.	Brick.
Curtis Bros.	Peterboro, Box 809.	Brick and Tile.
Dalton, Maurice.	Dresden, R.R. No. 3.	Tile.
DeLaplante, J. E., & Co.	Toronto, 1000 Gerrard St., E.	Brick.

BRICK AND TILE PLANTS, 1921—*Continued*.

Name	Address.	Product.
Deller, Albert E.	Vienna	Brick, Tile and Blocks.
Deller Bros.	Norwich, R.R. No. 2	Brick, Tile and Hollow Blocks.
Deller, Wm. H.	Thorndale, R.R. No. 4	Tile.
Dolan, John	Watford, R.R. No. 2	Tile.
Dominion Sewer Pipe and Clay Industries, Limited	Aldershot and Swansea	Brick, Blocks and Tile.
Don Valley Brick Works.	Toronto, 714 Dominion Bank Building	Common, Pressed and Tapestry Brick, Blocks.
Donaldson, S. E.	Harriston, R.R. No. 4	Tile.
Dublin Brick and Tile Company	Dublin	Brick and Tile.
Elliott, Charles	Bluevale	Brick and Tile.
Elliott, Wm.	Glenannan	Brick and Tile.
Elliott, Jas., Jr.	Sault Ste. Marie,	
	519 Wellington St., N.	Common and Rug Brick.
Fort William Brick and Tile Company	Ft. William, 509 Victoria Avenue	Brick.
Fox, Geo. J.	Dresden	Brick.
Frid Bros.	Hamilton	Brick.
Frid, Geo., Company	Hamilton, Main St., W.	Brick.
Fraser & Leith	Blyth	Brick and Tile.
Gardiner, William	Blenheim	Brick and Tile.
Godfrey & Co., Thos.	Carleton Place	Brick.
Grigg, William	Thedford, R.F.D. 1	Tile.
Hallatt, Wm.	Merlin	Tile.
Hallatt & Son, H.	Comber	Brick, Tile and Blocks.
Halton Brick Co., Ltd.	Terra Cotta	Pressed Brick.
Hamilton Pressed Brick Co., Limited	Hamilton, Kensington Ave., S.	Pressed Brick.
Hill, Aaron	Essex	Tile.
Hill, A. W.	Coatsworth, R.R. No. 1	Brick and Tile.
Hill Brick Co.	Madoc	Brick.
Hinde Bros.	West Toronto	Brick.
Hirecock Bros. & Company	Bowmanville	Brick and Tile.
Hitch, Mrs. Susan	Ridgetown	Brick and Tile.
Hitch, Thos.	St. Thomas, Box 254	Brick and Tile.
Holland & Son, William	Ruscomb	Brick and Tile.
Howlett, Fred.	Petrolia	Brick and Tile.
Huntsville Brick Co.	Huntsville, Box 308	Brick.
Interprovincial Brick Co. of Canada, Ltd., The	Toronto, 30 Toronto St.	Pressed Brick.
Jackson Bros.	Brantford	Brick.
Janes, D. A.	Mt. Brydges	Brick and Tile.
Jamieson Lime Co.	Renfrew	Brick and Tile.
Jaspersen Brick and Tile Co.	Kingsville	Brick, Hollow Blocks and Tile.
Jeffrey, Leon	Zurich, R.R. No. 2	Brick and Tile.
Jervis & Son, John	Dorchester Station	Brick and Tile.
Johnson, Jas., Sr.	Pembroke, R.R. No. 3	Brick.
Kerr, Fred	Crediton	Brick.
Koebel, Joseph Z.	St. Clements	Tile.
Kruse Bros.	Seaforth, R.R. No. 3	Brick and Tile.
Kuhn, Jerry H.	Centralia, R.R. No. 2	Tile.
Labey & Son, Geo. A.	Foxboro	Tile.
Lindsay, Stephen	Wallaceburg	Tile.
MacKay Bros.	Dutton	Tile.
Martin Estate, David	Thamesville	Tile.
McCormick Bros.	Watford, R.R. No. 5	Brick and Tile.
McGregor & Gammage	Dresden, R.R. No. 2	Tile.
McIvor Bros.	Cobourg, Box 636	Brick.
McLoughlin, Jno	London, 1044 William St.	Brick.
McMahon, Robert	Kerwood, R.R. No. 2	Tile.

BRICK AND TILE PLANTS, 1921—*Continued.*

Name.	Address	Product.
Merkley's, Ltd.	Ottawa, 53 Queen St.	Brick.
Middleton, Chas.	Wyoming	Tile.
Mills, Geo. E.	Hamilton, 614 King St. E.	Brick.
Milton Pressed Brick Co., Ltd.	Milton.	Pressed Brick.
Miner, J. T.	Kingsville, R.R. No. 2	Tile.
National Fire Proofing Co. of Canada, Ltd.	Toronto, 601 Dominion Bank Building	Tile and Blocks.
New, Edward	Hamilton, Dundas Rd.	Brick.
Norton, Alsey	Bolton.	Tile.
O'Dell, Albert & Henry	Ingersoll.	Brick, Tile and Blocks.
Ontario Brick and Tile Plant	Mimico.	Brick, Tile and Blocks.
Ontario Paving Brick Co., Limited	West Toronto.	Brick.
Ollman Bros.	Hamilton, Macklin St.	Brick.
O'Reilly, T. E.	Ottawa, 320 Bay St.	Brick.
Ott Brick and Tile Mfg. Co., Ltd., The	Kitchener.	Brick, Tile and Blocks.
Ottawa Brick Mfg. Co., Limited, The	Ottawa, 53 Queen St.	Brick.
Owen Sound Brick Co., Limited, The	Owen Sound	Brick.
Paxton & Bray	St. Catharines, Queenston Street	Brick.
Pears & Son, James	Toronto, Eglinton Ave., W.	Brick.
Pembroke Brick Co., The	Pembroke.	Brick.
Phillips & Son, Thos.	Lucknow, R.R. No. 2	Tile.
Phippen & Field	Toronto, Dawes Road	Brick.
Phinn Bros.	London, St. James Park	Brick and Tile.
Piggott & Co., Geo.	Mount Dennis, 20 Guestville Ave.	Brick.
Port Credit Brick Co., Limited, The	Port Credit	Pressed Brick.
Price & Cumming	Humber Bay, Salisbury Avenue	Brick.
Price & Smith	Toronto, 458 Greenwood Avenue	Brick.
Price, Ltd., Jno.	Toronto, 395 Greenwood Avenue	Brick.
Richardson & Son, James	Kerwood	Brick and Tile.
Rollins, D. W.	Belleville, R.R. No. 4	Brick.
Shale Products, Ltd.	Inglewood	Brick.
Snelgrove, A.	Beaverton	Brick and Tile.
Sproat, Wm. M.	Seaforth, R.R. No. 4	Brick and Tile.
Standard Brick Co., Ltd.	Toronto, 363 Broadview Avenue	Brick.
Stroh, M. C.	Conestogo	Brick and Tile.
Superior Tile Co., Limited	Port William	Common and Tapestry Brick.
Telford, John C.	Southwold	Tile.
Tilbury Brick and Tile Co., Ltd., The	Tilbury	Brick, Tile and Blocks.
Tolson, Mrs. Margaret J.	Highgate, R.R. No. 1	Brick and Tile.
Tope Estate, Richard	Hamilton, 171 Queen St., S.	Brick.
Toronto Brick Co.	Toronto, 60 Victoria St.	Brick.
Turner & Co., C. B.	Toronto, 894 Bathurst St.	Brick.
Wagstaff & Co., A. H.	Toronto, 348 Greenwood Avenue	Brick.
Wagstaff, Charles	Lindsay, R.R. No. 4	Tile.
Waide, J. C.	London, 1010 Adelaide St.	Brick.
Waite, John E.	Forrester Falls	Brick and Tile.
Wallace & Son, R.	North Bay	Brick.
Warwick Brick Works	London, 647 Grosvenor St.	Brick.
Whitby Brick and Clay Products Co., Ltd.	Whitby, Box 96	Brick.
Wi's n, Samuel & Sons	Paisley, R.R. No. 2	Brick and Tile.
Wich Bros.	Paisley, Box 220	Brick and Tile.
Windsor Brick and Tile Co.	Windsor, 201 Exchange Building	Brick, Tile and Blocks.
Woodslee Brick and Tile Co.	Woodslee	Brick and Tile.
Wright & Sons, Geo.	Comber, Box 56	Tile.
Wright, J. C.	Proton.	Brick and Tile.

Portland Cement

The capacity of the plants operated during the year was 12,560 barrels per day. An average of 883 men were employed, and wages amounted to \$1,228,460.

Following is a list of the operating plants:—

PORTLAND CEMENT PLANTS OPERATING IN 1921.

Company.	Location of Plant.	Head Office Address.
Canada Cement Company, Ltd.		Herald Bldg., Montreal, Quebec.
Plant No. 4	Thurlow tp.	
Plant No. 5	Thurlow tp., near Belleville	
Plant No. 8	Port Colborne	
Hanover Portland Cement Co., Ltd., The	Hanover	Hanover.
St. Marys Cement Co., Limited	St. Marys	St. Marys.

The following table gives details of the industry in 1913, during the war period and subsequently:—

PORTLAND CEMENT STATISTICS, 1913-1921.

Year	No. of Operating Plants.	Stock on hand Dec. 31st bbls.	Sales.		Average Price per bbl. (350 lbs.)
			Barrels.	Value	
				\$	\$
1913..	13	450,213	3,802,321	4,105,455	1.08
1914..	11	846,562	2,665,650	2,931,190	1.10
1915..	7	755,799	2,302,242	2,534,537	1.10
1916..	7	380,458	2,143,949	2,242,433	1.05
1917..	6	567,261	2,063,231	2,934,271	1.42
1918..	4	473,184	1,226,244	1,910,839	1.56
1919..	5	278,188	2,022,575	3,659,720	1.81
1920..	5	248,142	2,035,594	4,377,814	2.15
1921..	5	174,686	2,723,072	6,425,266	2.37

In the United States the factory price per barrel of 380 pounds ranged from \$1.13 in the East to \$2.58 in the West, the average price being \$1.89 per barrel.

Concrete Products.—The term “concrete” as usually understood refers to a compact mass of sand and gravel or crushed stone bound together by Portland cement. Monolithic concrete construction is not considered in this report, which deals only with moveable concrete products. In the United States approximately one barrel of cement is used to one ton of aggregate. As the materials entering into concrete receive individual consideration, the statistics of production of concrete products are not included in the summary of mineral output of the Province (Table I).

In 1921, there was an output of 441,243 concrete brick, 801,748 drain pipe, and 151,247 sewer pipe and culvert tile. For the most part the industry is not carried on during the winter months. Detailed statistics for the past five years follow:

CONCRETE PRODUCTS STATISTICS, 1917-1921.

Schedule	1917	1918	1919	1920	1921
Brick	\$ 1,420	1,290	10,631	11,117	9,235
Blocks, sills and caps	\$ 8,312	41,362	147,895	382,994	409,722
Drain tile	\$ 90,586	81,351	142,072	338,286	70,412
Sewer pipe and culvert tile	\$	..	..	..	317,811
Artificial stone and other products	\$	..	..	..	87,701
Total value of output	\$ 100,318	124,003	300,598	732,397	894,881
Average period of operation	days 105	122	108	161	224
Employees	No 105	72	148	218	230
Wages	\$ 28,641	25,901	90,653	212,014	253,141

PRODUCERS OF CONCRETE PRODUCTS, 1921.

Producer.	Location.	Kind of Product Made.
Andrews, S. J.	Clinton	Building Blocks, Drain Pipe, Sewer Pipe and Culvert Tile.
Anthistle, W. J.	London	Vaults.
Arthur, Corp. of Township of	Kenilworth	Sewer Pipe and Culvert Tile.
Ashman, T. J.	London	Building, Blocks, Heads and Sills.
Banks, John	London	Building Blocks, Artificial Stone.
Bawden, F. W.	Exeter	Building Blocks, Drain Pipe, Posts.
Beuglas, Jas.	Bright	Sewer Pipe and Culvert Tile.
Bowers, E. G.	Cottam	Building Blocks, Drain Pipe, Culvert Tile, Sewer Pipe.
Bishop, Thos. Wm.	Ridgeville	Cement Bricks, Building Blocks, Drain Pipe, Sewer Pipe and Culvert Tiles, Artificial Stone, Caps, Posts.
Brigden, Henry	Bruce	Building Blocks.
Brown, D. L.	Sudbury	Cement Bricks, Building Blocks.
Burkholder, George	Whitevale	Drain Pipe.
Calder, James	Fergus	Sewer Pipe and Culvert Tile.
Corinthian Stone Co.	Guelph	Artificial Stone.
Cross Builders Supply Co., Ltd.	Windsor	Building Blocks.
Concrete Pipe and Products Co.	Hamilton	Building Blocks, Drain Pipe, Sewer Pipe, Culvert Tile, Septic Tanks, Artificial Stone.
Canadian Concrete Products Co.	Chatham	Sewer Pipe and Culvert Tile, Pipe Carrier Foundations, Battery Wells, Battery Boxes.
Cast Stone Block and Machine Co.	Windsor	Cement Bricks, Building Blocks, Machinery Sales, Cement, Granite and Gravel Sales.
Chatham Cement Tile and Block Co.	Chatham	Building Blocks, Drain Pipe.
Christie Concrete Products	Lindsay	Cement Bricks, Building Blocks, Drain Pipe, Sewer Pipe, Culvert Tile, Artificial Stone.
Clarkson Cement Tile and Brick Co.	Toronto	Cement Bricks, Building Blocks, Drain Pipe, Sewer Pipe and Culvert Tile, Artificial Stone.
Dewitt, W. J.	Locust Hill	Sewer Pipe and Culvert Tile.
Deline, L.	Enterprise	Building Blocks, Sewer Pipe and Culvert Tile.
Doidge, James A.	Hamilton	Building Blocks, Drain Pipe.
Elridge, George	Sarnia	Building Blocks.
Elliott, J. A.	Dunsford	Building Blocks.
Fletcher & Son, J. H.	Ridgeville	Building Blocks, Cistern Block.
Flowers, Wm. T.	Caledonia	Building Blocks, Sewer Pipes and Culvert Tile.

PRODUCERS OF CONCRETE PRODUCTS, 1921—*Continued.*

Producer.	Location	Kind of Product Made.
Fulton, John	Pakenham	Sewer Pipe and Culvert Tile.
Garnet & Sons, Thos.	Port Hope	Cement Bricks, Building Blocks, Sewer Pipe and Culvert Tile.
Gillis, Alfred	Galt	Cement Bricks, Building Blocks, Artificial Stone, Lawn Vases and Laundry Tubs.
Granite Concrete Block Co.	Toronto	Building Blocks, Lintels.
Hall & Tampling	Dunnville	Building Blocks.
Hare, John	Markham	Building Blocks, Sewer Pipe and Culvert Tile.
Hewitt & Son, A. B.	Princeton	Building Blocks, Drain Pipe.
Hunt & Sons, J. W.	Mount Forest	Drain Pipe, Sewer Pipe and Culvert Tile.
Hyndman, Jno.	Gorrie	Drain Pipe, Sewer Pipe and Culvert Tile.
Independent Concrete Pipe Co.	Woodstock	Drain Pipe, Sewer Pipe and Culvert Tile.
Ingrouille, Stephen	Strathroy	Sidewalks, Outside Coffin Boxes.
Jacques, Ulderie	Windsor	Building Blocks.
Kilbourne & Son, H.	London	Building Blocks, Artificial Stone.
Kingston Cement Products—Horace F. Norman.	Kingston	Building Blocks, Artificial Stone, Grave Vaults, Ornaments.
Kinzel Bros.	Preston	Building Blocks.
Lefebvre, Jos.	Windsor	Building Blocks.
Lesperence, Peter J.	Ford	Cement Bricks.
Lishman, W. H.	Cayuga	Cement Bricks, Building Blocks, Sewer Pipe and Culvert Tile.
McQueen, Alex.	Moorefield	Cement Bricks, Drain Pipe, Sewer Pipe and Culvert Tile.
McLenaghan, W. A.	Essex	Building Blocks.
Marty, Emil	St. Catharines	Building Blocks.
Mitchell, Ralph R.	Niagara Falls	Building Blocks.
Miller, Thos.	Sandwich	Building Blocks.
Morse, W. O.	Campbellville	Sewer Pipe and Culvert Tile.
Ord, John A.	Guelph	Drain Pipe.
Oakes, Sam	Burlington	Cement Bricks, Building Blocks.
Oil Springs Tile and Cement Co.	Oil Springs	Cement Window Sills, Building Blocks, Drain Pipe.
Page, George Leslie	Lucknow	Drain Pipe.
Palm, Jacob	Mildmay	Sewer Pipe and Culvert Tile.
Peerless Artificial Stone Co.	Toronto	Artificial Stone, Laundry Tubs.
Piaff, Wm. E.	Hensall	Cement Bricks, Building Blocks, Drain Pipe, Sewer Pipe and Culvert Tile, Verandah Posts and Caps.
Reid, M. P.	Kingston	Cement Bricks, Building Blocks.
Robidoux, H. L.	Ainherstburg	Cement Bricks, Building Blocks, Drain Pipe, Sewer Pipe and Culvert Tile, Artificial Stone.
Robinson, Ed.	Mitchell	Drain Pipe, Sewer Pipe and Culvert Tile.
Ross & Son, Chas.	Dunnville	Sewer Pipe and Culvert Tile.
Russelo, Howard	Leamington	Building Blocks, Sewer Pipe and Culvert Tile.
St. Onge, Hormidas	Windsor	Building Blocks.
Schmidt, J. T.	Waterloo	Cement Bricks, Drain Pipe, Sewer Pipe and Culvert Tile.
Schram, A. J.	Camlachie	Drain Pipe.
Shoemaker, Allen	Kitchener	Drain Pipe.
Shovel Bros.	Owen Sound	Sewer Pipe and Culvert Tile.
Smith, Albert	West Lorne	Cement Bricks, Building Blocks.
Smith, Allan & C.	Acton	Building Blocks, Sewer Pipe and Culvert Tile, Sills and Lintels.
Smithson, Frank	Leamington	Sewer Pipe and Culvert Tiles.

PRODUCERS OF CONCRETE PRODUCTS, 1921—*Continued.*

Producer.	Location	Kind of Product Made
Somerville & Son, W. G.	Welland.....	Building Blocks, Sewer Pipe and Culvert Tile.
Stanley, J.	Stanley Corners...	Cement Bricks, Building Blocks, Sewer Pipe and Culvert Tile, Sills, Chimney Base and Crown.
Stinson, R. H.	Omemece.....	Sewer Pipe and Culvert Tile.
Sydenham Block and Tile Co.	Wallaceburg....	Building Blocks.
Taylor & Hall.....	Peterboro.....	Building Blocks, Sewer Pipe and Culvert Tile.
Telford, Peter.....	Holland Centre...	Drain Pipe, Sewer Pipe and Culvert Tile, Well Blocks, Troughs and Reducers.
Theaker, Wm.	Bartonville....	Building Blocks, Window Sills, Lintels.
Tigert, Jno.	Port Albert....	Drain Pipe, Sewer Pipe and Culvert Tile.
Watts, Alfred.....	Tillsonburg....	Building Blocks, Sewer Pipe and Culvert Tile, Window Sills and Pier Caps.
White, Sidney....	St. Catharines...	Building Blocks.
Whitlock, Petr.	Hensall.....	Building Blocks, Sewer Pipe and Culvert Tile.
Williams, E. J.	Wheatley....	Building Blocks, Drain Pipe, Sewer Pipe and Culvert Tile, Artificial Stone, Flower Pots, Sidewalks.
Winchester Cement Block and Tile Mfg. Co.	Winchester....	Drain Pipes.
Young & Son, John.....	Ridgeway....	Building Blocks, Sewer Pipe and Culvert Tile.

Lime

The day of small lime-kilns perched on a hillside or nestling on the river bank has passed. They have given way to modern plants capable of producing more and better lime. Following the introduction of Portland cement nearly a century ago, lime was gradually displaced to some extent for construction work. In recent years investigation has proved that hydrated lime mixed with cement mortar or concrete mixtures produces beneficial effects. It improves the workability, facilitates passing concrete through chutes, and increases the density and water-tightness. The strength of cement mortar is increased when quantities up to 10 per cent. by weight of hydrated lime are added to or substituted for Portland cement. On the other hand where great loads are carried and where work is conducted under freezing conditions cement in lime mortar has distinct advantages.

Statistics of lime marketed or used during the past five years are given in the following table:

LIME STATISTICS, 1917-1921.

Year.	Lime Marketed.						Fuel Cost \$	Em- ployees.	Wages \$
	Hydrated.			Total Lime. (Hydrated and Quicklime.)					
	Tons.	Total Value. \$	Per Ton. \$	Bush.	Value. \$	Ave. Price per bush. c.			
1917				2,820,507	657,364	23.3		325	262,132
1918				2,650,285	872,177	32.9	237,425	287	300,746
1919	30,454	307,342	10.09	3,991,572	1,268,290	32.4	302,144	363	366,686
1920	28,591	397,305	13.89	4,982,912	1,799,763	36.2	546,604	448	568,513
1921	26,863	381,749	14.58	3,530,547	1,344,188	38.0		366	341,826

Below are given the names of producers and the location of plants operated in 1921:—

LIME PRODUCERS, 1921.

Name of Owner or Company.	Location of Kilns.	Head Office Address.
Alabastine Co., Paris, The. (*)	Elora	Paris.
American Cyanamid Co.	Niagara Falls	Niagara Falls.
Beachville White Lime Co., Ltd.	Beachville	Beachville.
Bergin, Patrick	Napanee	Napanee.
Brunner Mond Canada, Limited.	Anderdon tp., near Am- herstburg.	Toronto, Bank of Com- merce Building.
Biederman, A. G.	Golden Lake	Golden Lake, R.R. No. 1.
Canada Lime Co.	Cobconk	Lindsay.
Chalmers Lime Works.	Owen Sound	Owen Sound.
Christie, Henderson & Co., Limited. (*)	Hespeler, Galt, Puslinch, Kelso	Toronto, 261 Crown Office Building
Dominion Sugar Company.	Chatham, Wallaceburg and Kitchener	Chatham.
Flieler, Edward.	Clarendon	Fernleigh.
Gallagher Lime and Stone Co., Limited.	Barton tp.	Hamilton.
Harvey, E., Limited.	Reckwood	Guelph.
Jamieson Lime Co.	Renfrew	Renfrew.
Jamieson, J. M.	Ross tp.	Forrester Falls.
Marshall, James.	Barton tp.	Hamilton.
O'Donohue, Michael.	Campbellford	Campbellford.
Parks Bros.	Beverly tp.	Troy.
Robertson Co., Limited, D.	Nassagaweya tp.	Toronto, 26 Queen St., E.
Smith, John S.	Kincardine	Kincardine.
Standard White Lime Co., Limited. (*)	Beachville, Guelph	Guelph.
Toronto Brick Co., Limited.	Cobconk	Toronto, 60 Victoria St.
Toronto Lime Co., Limited.	Dolly Varden	Toronto, 26 Queen St., E.
Toronto Plaster Co., Limited, The. (*)	Teeswater	Teeswater.
Vogan, Samuel.	Wiarton	Wiarton.
Weppler, Henry.	Glenelg tp.	Pricceville, R.R. No. 2.

*Producers of hydrated lime.

Sand=Lime Brick

Brick are made from sand and lime by compressing these materials in moulds and subjecting the resulting product to a steam bath. These brick will not stand rough handling before they are well cured. They find a ready market, particularly as inside brick, the cost being less than for the clay product.

Seven plants operated in 1921, the output being 36,482 M. worth \$534,531, or an average of \$14.64 per M. The industry gave employment to 131 men, whose wages totalled \$141,460. Production in 1920 was 21,703 M., worth \$407,766, or an average of \$14.72 per thousand.

The following plants were operated during the year:—

SAND-LIME BRICK PRODUCERS, 1921.

Name.	Location of Plant.	Address.
Caledon Brick Co., Ltd.	Caledon E.	171 Yonge St., Toronto.
Canada Sand-Lime Pressed Brick Co., Ltd.	West Toronto.	28 Symes Rd., Toronto
Toronto Brick Co., Limited.	Scarboro and Swansea.	60 Victoria St., Toronto.
West Lake Brick and Products Co.	West Lake.	R.R. No. 1, Pieton.
Willeox Lake Brick Co., Ltd.	Whitechurch tp.	Richmond Hill.
York Sandstone Brick Co., Ltd.	Gerrard St. and Victoria Avenue.	E. Toronto.

Sand and Gravel

Out of a total of 6,273,113 tons of sand and gravel reported, 2,943,959 tons was used for railway ballast; glass sand consumption was 135 tons; moulding sand 90,901; blast and engine sand 6,746 tons.

Following is a list of sand and gravel pit operators who marketed or used 1,000 cubic yards or more during the year:—

SAND AND GRAVEL OPERATORS, 1921.

Name of Owner or Company.	Material G = Gravel S = Sand	Location of Deposits	Address.
Aldborough, Township of	G.	Aldborough tp., lot A, con. 7.	Rodney.
Allan Bros.	S. and G.	Stop 19, Kingston Rd.	Toronto, 60 Birchcliffe Ave.
Allan, Mrs. M.	S.	Grantham tp., lot 7, con. 2.	St. Catharines, R.R. No. 4.
Armstrong Supply Co., Ltd., The.	S.	1143 York St., Hamilton.	Hamilton, 34 James St., N.
Ashton & Sons, E.	S.	Scarborough tp., Victoria Park, W.	Toronto, 1354 Queen St., E.
Bellyou, Norman E.	S. and G.	Murray tp., lot 6, con. 1.	Trenton, R.R. No. 4.
Bennett, Joseph.	S.	Searlett Rd., York tp.	Toronto, 145 Caledonia Rd.
Benson & Patterson.	S. and G.	Stamford tp., lot 17-18	Stamford.

SAND AND GRAVEL OPERATORS, 1921—*Continued*

Name of Owner or Company	Material G = Gravel S = Sand	Location of Deposits	Address.
Blair & Son, James.....	S.	Fitzroy tp., lot 22, con. 4.....	Arnprior.
Boyd Bros.....	G.	Osgoode tp., lot 27, con. 4.....	Osgoode.
Brantford, Corporation of City of.....	S. and G.	Brantford tp.....	Brantford, City Hall.
Brown & Sons, Wm.....	S. and G.	Smith tp., lot 19, con. 3 and lot 18, con. 2.....	Peterborough, Box 784.
Campbellford, Town of.....	S. and G.	Seymour tp., lot 5.....	Campbellford.
Carroll Bros.....	S.	Humberstone tp., lots 3, 4, 5, 6, 7, 8, 9, con. 1.....	Buffalo, N.Y., 490 Elliott Square.
Cleary, Thomas.....	S. and G.	Cornwall tp.....	Mille-Roches, Ont.
Conlon, John J.....	S.	Pelham tp., lot 4, con. 8.....	St. Catharines, 31 Maple St.
Construction and Paving Co. of Ontario, Ltd.....	S. and G.	Erin tp.....	Toronto, 708 Confederation Life Bldg.
Cotterill, Alfred A.....	S.	Westminster tp.....	London, 81 Briscoe St.
Crosthwaite, F.....	S.	Barton tp., lot 3, con. 3.....	Bartonville, Ont.
Cudmore, J. W.....	G.	Howard tp., lot 12, con. 1.....	Thamesville.
Dean, Harry F.....	G.	Middleton tp., con. 2.....	Tillsonburg, R.R. No. 2.
Dereham, Tp. of.....	S. and G.	Dereham tp., lot 16, con. 10.....	Mount Elgin.
Donald, Andrew.....	G.	Dereham, lot 22, con. 7.....	Ingersoll, R.R. No. 1.
Donaldson, W. J.....	S. and G.	Fitzroy tp., lot 27, con. 3.....	Arnprior.
Doyle, Wm.....	S. and G.	Oneida tp., lot 16, con. 4.....	Caledonia, R.R. No. 3.
Elgin, County Highways.....	S. and G.	Yarmouth tp., lot 3 con. 4; Aldborough tp., lot C, con. 7; Southwold tp., lot 13, con. 5.....	St. Thomas, Court House
Empire Limestone Co.....	S.	Sherkston.....	Buffalo, N.Y., 19 Hudson St.
Faulds, Morley.....	S. and G.	Southwold tp., lots 12 and 14, con. 5.....	Iona Station, R.R. No. 4.
Fonthill Gravel Co., Ltd.....	S.	Fonthill.....	Thorold.
Forbear Sand and Gravel Co.....	S.	Vaughan tp., lot 22, con. 3.....	Maple.
Foster, R.R.....	S. and G.	Ottawa, Gloucester tp.....	Ottawa, 278 Echo Drive.
Frid Bros.....	S. and G.	Hamilton, Dundas Rd. and Macklin St.....	Hamilton, Dundas Rd. and Macklin St.
Godson Contracting Co., Ltd.....	S. and G.	Brock tp., lot 12, con. 4.....	Toronto, 113 Manning Chambers.
Guelph, City of.....	G.	Guelph.....	Guelph, City Hall.
Hamilton Sand and Gravel, Ltd.....	S. and G.	Burlington Heights.....	Hamilton, 110 Queen St., N.
Harwich Township.....	S. and G.	Harwich tp.....	Blenheim.
Hoffman, Jas.....	S. and G.	City of Kitchener.....	Kitchener, 27 Pine St.
Hydro-Electric Power Commission.....	S.	Stamford tp.....	Toronto, 187 University Ave.
Iroquois Sand and Gravel Co., Ltd.....	S. and G.	Scarborough tp., lot 9, con. 2.....	Toronto, 1107 Royal Bank Bldg.
Kent, County of.....	S.	Raleigh tp.....	Chatham.
Kilbourne & Son, Harvey.....	S.	Westminster tp., Wharnciffe Rd.....	London, 9 Cove Road.
Kingston Sand and Gravel Co.....	S.	Kingston tp., lots 33-34, con. 5.....	Kingston, 179 Stuart St.

SAND AND GRAVEL OPERATORS, 1921—*Continued*

Name of Owner or Company	Material G = Gravel S = Sand	Location of Deposits	Address
Larter, Chas.	S. and G.	North Dumfries tp.,	Galt, 76 Chalmers St.
Lambton, County of	S.	Enniskillen tp., lot 9, con. 13.	Sarnia.
Lane, George.	G.	Thurlow tp., con. 2.	Bellville.
Le Viness & Sons, A.	S.	Stamford tp., lot 37.	Stamford.
Lyons Fuel and Supply Co.	G.	Mile 34, A.C. Ry.	Sault Ste. Marie, Ont.
Malahide tp.	G.	Malahide tp., lot 21, con. 6.	Aylmer.
Malloy, Wm. B.	S. and G.	Ellice tp., lot 8, con. 4.	Sebringville, R.R. No. 1.
Maple Sand, Gravel and Brick Co.	S. and G.	Vaughan tp., lots 21-24 con. 3.	Toronto, 454 King St., W
McAlpine, Daniel.	G.	Dunwich tp., lot 10, con. A.	Dutton.
Middlesex, County of	S. and G.	Numerous places.	London, County Bldgs.
Millard, David.	S.	Whitechurch tp., lot 33, con. 3.	Newmarket.
Mills, James.	S. and G.	Downie tp., lot 12, con. 5.	Stratford, R.R. No. 3.
Moyer, Lovclace Co., Ltd.	S.	Pelham tp., lots 6 and 7, cons. 8 and 9.	St. Catharines.
Oakland Sand and Gravel Co.	S. and G.	Oakland tp., con. 3.	Niagara Falls.
Ollman Bros.	S.	Hamilton, Macklin St.	Hamilton, Macklin St.
Ontario Highways Dept.	S. and G.	Numerous pits.	Parliament Bldgs., Toronto.
Paris Sand and Gravel Co.	S. and G.	S. Dumfries tp., lo 34, con. 1.	Paris, R.R. No. 2.
Peterborough, City of	S. and G.	Hilliard farm, block G., south of north city limit.	Peterborough, 133 Sim- coe St.
Ponsford, A. E.	S. and G.	Yarmouth tp., lot 1, con. 7.	St. Thomas, 605 Talbot St.
Porter, Thompson.	S.	York tp., lots 28 and 29	Mt. Dennis, 866 Weston Road.
Prior, Elston M.	G.	Yarmouth tp., lot 16, con. 4.	St. Thomas, R.R. No. 4.
Quick, Chas. R.	S. and G.	Westminster, Manor Park.	London, 101 Briscoe St.
Quigley, B. C.	S. and G.	Saltfleet tp., lot 29, con. 3.	Hamilton.
Redden, Henry.	S. and G.	Campbellford, Kent St.	Campbellford.
Rideau Canal Supply Co., Ltd.	S.	Hogs Back, Gloucester tp.	Ottawa, Rideau Canal Basin.
Sand and Supplies, Ltd.	S. and G.	Waterloo Co., near Ayr	Toronto, 54 University Ave.
Sarjeant Co., The.	S. and G.	Barrie, James and Pen- etang Streets.	Barrie, Dunlop St.
Shannon, Hiram L.	S. and G.	Richmond tp., lot 6, con. 3.	Napanee, R.M.D. No. 5.
Shirk, Geo. M.	S. and G.	Bridgeport.	Bridgeport.
Skinner, Robt.	G.	Usborne tp., lot 11, con. 5.	Exeter.
Sleeman, P.	S. and G.	Hope tp., lot 9, con. 2.	Port Hope.
Smith Estate (F. S. Scott).	S. and G.	N. Dumfries tp., lot 8, con. 12.	Galt.
Stothart, James.	S.	Smith tp., lot 17, con. 2	Peterborough, R.R. No. 4.
Sulley, W. J.	S.	Darlington tp., lot 28, con. 4.	Courtice.

SAND AND GRAVEL OPERATORS, 1921—*Continued*

Name of Owner or Company	Material G = Gravel S = Sand	Location of Deposits	Address
Tarentorus, Township of.....	S. and G.	Tarentorus tp., sec. 29	Sault Ste. Marie.
White & Co., Homer.....	G.	Hallowell tp., lot 22.....	Pictou.
Wilcox, Henry.....	S.	Stamford tp., part lots 4 and 17.....	Niagara Falls, 209 Bridge St.
Windsor, Essex and Lake Shore Ry., Co.....	G.	Mersea tp., W. of Leamington.....	Kingsville.
Windsor Sand and Gravel Co., Ltd., The.....	S. and G.	Two miles west of Leamington.....	Windsor, 57 Hall Ave.
Wright & Co.....	S.	Korah tp., sec. 13.....	Sault Ste. Marie, 960 Queen St.
Yaek, Henry.....	S.	London tp., lot 12, con. 2.....	London.
Yarmouth, Township of.....	S.	Yarmouth tp., lot 8, con. 5.....	St. Thomas, Southern Loan Chambers.

The Department of Mines issues licenses and collects a royalty on the removal of sand and gravel from the beds of the great lakes and rivers. The revenue from this source accruing to the Ontario Government was \$112,996.95 for the calendar year of 1921, and the quantity of sand and gravel removed was 599,655 cubic yards. Following is a list of such licensees:

SAND AND GRAVEL LICENSEES, 1921.

Name of Company	Material. G = Gravel S = Sand	Location of Deposit	Address
Abitibi Power and Paper Co.....	S. and G.	Township of Rickard.	Iroquois Falls.
Cadwell Dredging Co., Ltd.....	G.	St. Clair River.....	Windsor.
Chatham Sand and Gravel Co.....	S. and G.	Thames River.....	Chatham.
Chick Contracting Co.....	G.	St. Clair River.....	Windsor.
Cameron Steamship Co.....	G.	St. Clair River.....	Detroit, 39 Buhl Bldg.
Department of Railways and Canals	G.	Niagara River.....	Ottawa.
Great Lakes Transportation Co.....	S.	Thunder Bay.....	Fort William.
Gleason, F. D., Coal Co.....	S. and G.	St. Clair River.....	Detroit, Mich., 28 Cam- pau Building.
Hadley Co., Ltd., The C. & J.....	S. and G.	Thames River.....	Chatham.
Homegardner Sand Co.....	S.	Dummy Foundation, Lake Erie.....	Sandusky, Ohio.
International Sand and Gravel Co., Kelley Island Lime and Transport Co.....	G.	St. Clair River.....	Detroit, 47 Can pau Bldg.
Lake Erie Sand Co.....	S. and G.	Lake Erie.....	Sandusky, Ohio.
	S.	Dummy Foundation, Lake Erie.....	Sandusky, Ohio.
Marysville Land Co.....	G.	St. Clair River.....	Marysville, Mich.
National Sand and Material Co.....	S. and G.	Lake Erie.....	Welland.
Niagara Sand Corp. (J. E. Carroll and T. E. Milburn).....	S. and G.	Niagara River.....	Buffalo, N.Y., 915 White Building.
Superior Sand and Gravel Co.....	S. and G.	St. Clair River.....	Detroit, Mich.
United Fuel and Supply Co.....	G.	St. Clair River.....	Detroit, Free Press Bldg.

Stone

As noted in Table I the total output of stone of all grades was 2,716,080 * tons valued at \$4,167,582. The tonnage of sandstone was 3,267; trap 152,899; and granite 6,153. Of the limestone sold or used over 90 per cent. was in the form of crushed stone, mainly for concrete and road purposes.

The table which follows shows the valuation of the several kinds of stone marketed or used over a five-year period:

VALUE OF STONE PRODUCTION, 1917-1921.

Year	Limestone	Sandstone	Trap	Granite	Marble	Total
	\$	\$	\$	\$	\$	\$
1917	728,975	115,932	70,570	25,575	.....	941,052
1918	820,985	145	24,744	23,334	.....	869,238
1919	1,112,340	5,544	82,995	10,683	19,360	1,230,922
1920	3,786,263	10,502	92,630	55,277	300	3,944,972
1921	3,934,045	6,423	158,467	68,647	.....	4,167,582

STONE QUARRY OPERATORS, 1921.

Name of Owner, Firm or Company	Location	Kind of Stone
Abitibi Power and Paper Co.	Farr quarry, Bucke tp.	Limestone.
Abrams, J. M.	Gananoque	Granite.
Alabastine Co., Paris, Ltd.	Nichol tp.	Limestone.
Ball, B. W.	Woodhouse tp.	Limestone.
Bergin, Patrick	Napanee	Limestone.
Bolender Bros.	Haliburton	Crystalline Limestone.
Britnell & Co., Ltd.	Somerville tp.	Limestone.
Brown, A. C.	Leeds tp.	Monumental Granite.
Brantford and Hamilton Electric Railway Co., Ltd.	Ancaster	Limestone.
Bruce Mines Trap Rock Co., Limited	Bruce Mines	Trap.
Brunner, Mond Canada, Ltd.	Amherstburg	Limestone.
Caldwell Bros.	Gloucester	Limestone.
Campbell and Lattimore	Findley	Granite.
Carleton County (W. J. Farmer and Caldwell Bros.)	Osgoode and Gloucester tps.	Limestone.
Canada Crushed Stone Corporation, Ltd.	Dundas	Limestone.
Cayuga Stone Co.	Nelles	Limestone.
Cook, J. S., & Son	Warton	Limestone.
Crushed Stone, Limited	Eldon	Crushed Limestone.
Dept. of Prov. Secty., Ont. Prisons and Asylums Branch	Guelph tp.	Limestone.
Department of Public Highways	Toronto	Limestone and Dolomite.
Fort William, Corp. of the City	Rifle Range, Ft. William	Trap Rock.
Foster & Cram	Merevale Rd., City View Ottawa	Limestone.
Gallagher Limestone and Stone Co.	Hamilton	Limestone.
Gosselin, Chas.	Quarries, Russell Co.	Limestone.
Gow, James	Fergus	Limestone, Dolomite.
Hagersville Crushed Stone Co., Ltd.	Hagersville	Limestone.
Hagersville Quarries	Walpole tp.	Limestone.
Haldimand County Good Roads System	Nelles and Dunnville	Limestone.

STONE QUARRY OPERATORS, 1921—*Continued*

Name of Owner, Firm or Company	Location	Kind of Stone
Hamilton, Corporation of	Hamilton	Limestone.
Henderson Farmers' Lime, Ltd.	Woodstock	Limestone.
Higginson, Geo., & Son	Coldwater	Limestone.
Hildreth, Chas.	Barton, lot 6, con. 12	Limestone.
Horne, Wm.	Butler	Granite.
Hydro-Electric Power Commission	Brant tp.	Limestone.
Kingston Penitentiary Quarries	Portsmouth	Limestone.
Lally, E.	Smithville	Limestone.
Law Construction Co., The	Bertie tp.	Limestone.
Lincoln County	N. Grimsby tp.	Limestone.
Longford Quarry Co., Limited	Longford Mills	Limestone and Riprap.
McNeely, D. R.	Beckwith tp.	Limestone.
Markus, Wm., Ltd.	Pembroke	Limestone.
Middleton, John N.	Ancaster	Limestone.
McDonnell, George	Wolfe Island tp.	Limestone.
Mond Nickel Co., Ltd.	Drury and Levaek tps.	Trap Rock.
Mills, Jas.	Napanee	Limestone.
Morrison Bros.	Coehill	Granite.
Muskoka Quarries, Ltd.	Draper tp.	Granite.
Ontario Rock Co., Ltd.	Belmont and Methuen tps.	Trap Rock.
Ontario Stone Corporation, Limited	North Orillia tp.	Limestone.
Ottawa Improvement Commission	Corner Bell and Carling, Ottawa	Crushed Stone.
Owen Sound, Board of Works	Owen Sound	Limestone.
Pearce Company, Ltd.	Marmora	Limestone.
Perkins, Geo. A.	Owen Sound	Limestone.
Point Anne Quarries, Limited	Point Anne	Limestone.
Reid, C. F.	Odessa	Sandstone.
Rideau Canal Supply Co., Limited	Ottawa	Limestone.
Robertson, D., & Company, Limited	Milton	Sandstone.
Robillard, H., & Son	Ottawa	Limestone.
Roddy & Monk	Kingston	Limestone.
Rogers, F., & Co.	Chinguacousy tp.	Sandstone.
Standard White Lime Co., Limited	Beachville	Limestone.
Streets and O'Brien	Leeds tp.	Granite.
Thames Quarry Co.	St. Marys	Limestone.
Walker Bros.	Thorold	Limestone.
Wallace, R., & Sons	Stephen St., Kingston	Limestone.
Webber, John	Dunn tp.	Limestone.
Webster, Jas. S.	Foot of Augusta St., Galt.	Limestone.
Wentworth Quarry Company, Ltd.	Saltfleet tp.	Limestone.
Wilson, Geo. S.	Perth, R.R. No. 3	Sandstone.

Mining Divisions

Following is a summary of the comments by Mining Recorders on the subject of mining and prospecting activity in their respective Divisions:

Sudbury—A little more prospecting activity than usual has been manifested in the neighbourhood of Lake Wanapitei.

Porcupine—Promising gold finds are reported in Ogden, Bristol and Cody townships. Favourable results from diamond-drilling have been obtained at the Night Hawk Peninsular mine. The Dome, Hollinger and McIntyre mines are working to capacity and mill additions under construction at the last mentioned will considerably increase the production. The power situation is causing uneasiness in the camp, but hydro-electric developments are under way at Sturgeon Falls and Indian Chutes, that should improve conditions before next winter.

Larder Lake—There was activity in all parts of this Division during the year 1921. In McVittie, Gauthier, Lebel and Teck townships, particularly, a large number of claims have been staked with good gold values, resulting in several groups of

claims being purchased by well-known mining companies from Porcupine and Cobalt. From reports, there are at present a great many prospectors scattered throughout the whole of this Division, and it would appear that in at least 75 per cent. of the townships good gold values have been obtained. Every indication points to 1922 being a very busy year.

Sault Ste. Marie—Receipts for the year were about \$1,100 in excess of 1920. Mr. Thomas Murphy made an important discovery of gold in Township 28, Range 27, on the Algoma Central Railway. This property is now called the Goudreau Gold Mines, Limited. While this discovery was made on Algoma Central Railway lands, nevertheless, it has a great bearing on the future of the surrounding areas. In Townships 48 and 47, and near Dog lake to the northeast, there was considerable activity in developing gold properties, thus making the Goudreau belt 25 miles in length. At Mile 60 on the Algoma Central Railway the Clark Iron Mining Company have given a contract to the Smith & Travers Diamond Drill Company to drill their iron claims in Township 22, Range 13. If they are successful in locating a body of ore, the Clark Iron Company will open up the mine. In November last a silver discovery was made in Township 188, north of Clear lake, and 28 miles north of the town of Thessalon. A rush started to the vicinity, with the result that the township is pretty well staked. Staking extended to Township 182, to the east of 188.

Kowkash—This Division was neglected almost entirely during the Great War as few miners could be employed; however, returned soldiers appear to be seriously interested in many of the old holdings, and development of the area may be looked for in the near future.

Timiskaming—Most of the prospecting in this Division during the past year was in the township of Bryce, where a discovery of gold was reported in the fall of 1920, and the beginning of 1921. There was less prospecting in 1921 than previously, owing no doubt to economic conditions, but the prospectors are very hopeful and are looking forward to 1922 for better results.

Gowganda—About 65 mining claims were staked for gold during September and October in Rankin and Doon townships, but as very little work has been performed on any of these claims it is too soon to say whether or not the new discovery will prove valuable.

Montreal River—No new discoveries were reported during the year. A large number of the claims recorded during 1921 are re-staking of former claims in Powell and Cairo townships.

Kenora—There has been marked activity in prospecting, as shown by the increase in the number of licenses issued and in the number of claims staked, and there are good indications that the year 1921 will show even a greater activity.

The two tables following show the work done in the offices of the Mining Recorders during 1921, the first table being for the fiscal year ending October 31, and the second for the calendar year.

MONEYS REMITTED BY MINING RECORDERS FOR THE FISCAL YEAR ENDING OCTOBER 31, 1921.

Mining Division*	Name of Recorder	Address	Purchase Price	Permits	Miners' Licenses	Recording fees, etc.	Total
			\$ c.	\$ c.	\$ c.	\$ c.	\$ c.
Sudbury	Campbell, C. A.	Sudbury	2,986 00	330 00	3,148 50	3,502 25	9,966 75
	Gauthier, G. H.	S. Porcupine	2,138 28		616 00	1,041 50	3,795 78
Porcupine	Donaghue, W. A.	S. Porcupine	1,977 53	70 00	1,087 00	1,906 75	5,041 28
Lardner Lake	Ginn, H. Geo.	Swastika	15,085 41		2,401 00	7,586 50	25,072 91
	Holland, H. E.	Kenora			597 00	297 50	894 50
Kenora	O'Flaherty, T. F.	Kenora			3 00	20 00	23 00
Sault Ste. Marie	Miller, W. N.	Sault Ste. Marie	873 01	60 00	1,369 00	1,385 97	3,688 98
Port Arthur	Morgan, J. W.	Port Arthur	1,649 20	50 00	1,812 25	1,472 25	4,983 70
Kowkash							
Gowganda							
Montreal River	Morgan, M. R.	Elk Lake	1,747 95	630 00	1,250 00	2,304 75	5,932 70
Timiskaming	McAulay, N. J.	Haileybury	664 45	30 00	4,834 00	1,287 25	6,815 70
Total			27,121 83	1,170 00	17,117 75	20,805 72	66,215 30

*The office of the Parry Sound Division was closed Oct. 31st, 1920 and all records transferred to the Department at Toronto.

SUMMARY OF BUSINESS OF THE SEVERAL MINING DIVISIONS FOR THE CALENDAR YEAR 1921

Schedule	Sudbury	Porcupine	Larder Lake	S. S. Marie	Pt. Arthur	Kowkash	Timiskaming & Cobden	Gowganda	Montreal River	Kenora	Total
1. Letters received.....	2,208	1,702	5,544	878	2,141	298	1,476	475	2,055	1,186	17,963
2. Letters written.....	1,668	1,631	5,291	479	2,098	295	993	375	1,586	1,097	15,513
3. Miners' Licenses issued.....	288	161	217	232	137	1	254	2	89	100	1,481
4. Miners' Licenses renewed.....	338	189	314	124	201	16	734	44	121	32	2,113
5. Mining applications re- corded.....	319	273	918	216	120	3	159	101	143	53	2,305
6. Mining applications can- celled.....	334	194	593	31	66	53	265	98	143	14	1,791
7. Agreements, transfers, etc., recorded.....	221	202	535	27	46	1	87	27	129	7	1,282
8. Amounts received for Min- ers' Licenses, Permits, Recording Fees, etc.....	\$6,425 10	\$4,379 75	\$10,546 25	\$3,421 75	\$2,817 25	\$132 50	\$6,201 25	\$1,161 50	\$3,144 00	\$1,011 75	\$39,241 10
9. Amount received as Pur- chase Money or Rentals.....	\$3,041 05	\$3,260 42	\$9,590 65	\$1,779 64	\$1,741 25	\$254 90	\$564 95	\$207 55	\$1,448 45		\$21,948 86
10. Claims of which survey- ors' plans were filled.....	43	69	184	11	14		3	11	44		379
11. Disputes entered.....	3	1	17		1				2		24
12. Disputed cases decided by Recorder.....	2		1						2		5
13. Appeals to Mining Com- missioner.....			1								1
14. Extensions of time.....	80	101	265	14	90	6	14	22	100	7	699
15. Certificates of Record.....	49	58	139	19	21	1	21	8	27	4	347
16. Certificates of Perform- ance of Work.....	52	64	148	16	21	3	11	10	24	3	352
17. Claims for which papers were forwarded to the Department for issue of title.....	49	36	120	19	9	3	11	9	10		266
18. Forest Reserve Permits issued.....				8	3	1	8	8	55		83
19. Substitute Miners' Licen- ses issued.....				1	1		10		1		13

Mining Revenue

The revenue for the fiscal year ending October 31st, 1921, is given in detail hereunder:

REVENUE FOR THE YEAR ENDING OCTOBER 31st, 1921.

Mining Sales.....		\$25,834 05
RENT—		
Mining Leases.....	\$13,654 78	
Licenses of Occupation.....	5,208 47	18,863 25
Fuel Investigation.....	8,625 99	
Coal Permits.....	8,815 05	17,441 04
Sand and Gravel Royalty.....	131,001 31	
Sand and Gravel Rental.....	3,160 00	134,161 31
Miner's Licenses.....	28,181 10	
Permits.....	1,240 00	
Recording Fees.....	22,051 22	51,472 32
MINING TAX ACT—		
Acreage Tax.....	37,581 11	
Profit Tax.....	183,821 80	
Gas Tax.....	21,450 01	
Gas Licenses.....	1,958 82	244,813 74
Casual Fees.....	1,150 39	
Patent Fees.....	486 36	
Temiskaming Testing Laboratories, fees.....	3,971 32	
Natural Gas Commissioner's Office, fees.....	70 00	
Draughtsmen, North Bay, fees.....	90 15	
Provincial Assay Office Fees.....	715 00	6,483 22
REFUNDS—		
Explorations and Investigations.....	2,238 83	
Natural Gas Commissioner's Office.....	476 51	
Mining Recorders.....	185 00	2,900 34
		\$501,969 27

MINING LANDS SOLD AND LEASED IN YEAR ENDING OCTOBER 31st, 1921.

District	Sales			Leases			Total		
	No.	Acres	Amount	No.	Acres	Amount	No.	Acres	Amount
			\$ c.			\$ c.			\$ c.
Temiskaming.....	232	9,445.29	19,434 36	129	3,465.29	568 04	361	12,910.58	20,002 40
Thunder Bay.....	10	345.25	811 88	9	381.20	381 20	19	726.45	1,193 08
Sudbury.....	19	735.73	2,010 00	29	1,041.29	723 91	48	1,777.02	2,733 91
Algoma.....	8	365.78	838 04				8	365.78	838 04
Kenora.....	1	12.50	15 65				1	12.50	15 65
Rainy River.....	2	74.00	222 00				2	74.00	222 00
Nipissing.....				8	307.78	30 78	8	307.78	30 78
Elsewhere.....	5	207.30	556 50				5	207.30	556 50
Total.....	277	11,185.85	23,888 43	175	5,195.56	1,703 93	452	16,381.41	25,592 36

Under the Mining Tax Act, a graduated tax is levied on the profits of mining companies in excess of \$10,000 per annum. The basal rate is 3 per cent., but there are special provisions for nickel-copper companies. The following statement, prepared by G. R. Mickle, Mine Assessor, gives details of the Profit Tax for the fiscal year ending October 31st, 1921:

DETAILS OF PROFIT TAX.

GOLD:

Hollinger Consolidated Gold Mines, Ltd., ...	\$76,042 54	
Dome Mines Company, Ltd., ...	8,110 77	
McIntyre Porcupine Mines, Ltd., ...	8,393 61	
Lake Shore Mines, Ltd., ...	1,929 05	
Teck-Hughes Gold Mines, Ltd., ...	618 96	
		\$95,094 93

SILVER:

Coniagas Mines, Ltd., ...	4,656 25	
Cobalt Lake mine (Mining Corporation of Canada)	1,235 42	
Central Operating Co., ...	324 11	
Kerr Lake Mining Co. Ltd., ...	4,929 86	
La Rose Mines, Ltd., ...	591 93	
Miller Lake O'Brien Mine (M. J. O'Brien, Ltd.)	2,342 66	
Nipissing Mining Company, Ltd., ...	12,401 44	
		26,481 67

NICKEL—COPPER:

International Nickel Co. of Canada, Ltd., ...	60,245 20	
Mond Nickel Co., Ltd., ...	2,000 00	
		62,245 20

Total \$183,821 80

Mining Companies Incorporated and Licensed

A synopsis of mining companies incorporated and licensed in Ontario during the past decade is given hereunder:

Year	Incorporated		Licensed	
	Number	Capital \$	Number	Capital \$
1912 ..	130	73,237,000	6	570,000
1913 ..	119	78,000,000	12	21,735,000
1914 ..	80	39,030,000	13	5,445,000
1915 ..	59	42,005,000	2	10,200,000
1916 ..	83	109,079,500	8	7,011,650
1917 ..	100	117,183,000	7	7,202,000
1918 ..	71	49,800,000	7	15,000,000
1919 ..	147	223,530,000	10	9,554,197
1920 ..	119	146,094,000	12	9,435,000
1921 ..	67	105,715,000	6	1,030,000

The mining companies incorporated in 1921 are shown in the list appended, together with head office, date of incorporation and amount of capital authorized.

MINING COMPANIES INCORPORATED IN 1921.

Name of Company	Head Office	Date of Incorporation	Capital
			\$
Acton Mines, Limited	Gananoque	April 27	100,000
Allied Porcupine Gold Mines, Limited	Toronto	Feb. 9	5,000,000
Almont Gold Mining Company, Limited	Toronto	June 25	1,000,000
A. L. Shaw Oil and Development Co., Ltd.	Toronto	May 10	500,000
Aster Gold Mines, Limited	Toronto	June 1	2,000,000
Blue Quartz Gold Mines, Limited	Toronto	Nov. 23	3,500,000
British Canadian Petroleum Co., Ltd.	Toronto	April 23	1,000,000
Burnand Gold Mines, Limited	Toronto	Oct. 7	2,500,000
Canadian Non-Metallic Minerals, Ltd.	Opeongo	April 7	40,000
Canyon Mines, Limited	Toronto	Aug. 19	(£) 200,000
Central Ontario Oil Fields, Limited	Peterborough	June 24	1,000,000
Chamberlain Coal and Oil Development Co., Ltd.	Shelburne	Feb. 4	2,000,000
Citics Service Oil Company, Limited	Hamilton	Feb. 11	5,000
Comfort-Kirkland Mines, Limited	Toronto	Feb. 21	1,500,000
Feldspar Glass, Limited	Bowmanville	Sept. 6	1,000,000
Fort Norman Oil Company, Limited	Toronto	Feb. 4	3,000,000
General Petroleum and Gas Company, Limited	Toronto	Mar. 19	500,000
Goldwyn Mines, Limited	Toronto	Oct. 12	2,000,000
Hermo Mining Company, Limited	Cobalt	Aug. 22	40,000
Hclgden Mines, Limited	North Bay	Dec. 10	1,000,000
Hcltyrex Gold Mines, Limited	Toronto	June 16	3,000,000
International Oil Gas and Development Co., Ltd.	Toronto	Oct. 10	510,000
Islet Exploration Company, Limited	Port Arthur	Jan. 3	250,000
Jackson Development Company, Limited	Port Arthur	Dec. 13	40,000
Kirkland Motherlode Limited	Toronto	June 10	2,500,000
K. M. B. Syndicate	Elk Lake	May 19	100,000
Lakeside Development Company, Limited	Toronto	Mar. 2	100,000
Lebel Lode, Limited	Cobalt	May 13	2,000,000
Lorrain Operating Company, Limited	Toronto	Nov. 24	40,000
Maisonville Mining Company, Limited	Toronto	Feb. 11	2,500,000
Majestic Gold Mines, Limited	Toronto	Jan. 24	1,000,000
Manley-O'Reilly Gold Mines, Limited	Toronto	Sept. 20	3,500,000
Mars Mines, Limited	Toronto	May 28	3,000,000
Matheson Gold, Limited	Toronto	June 16	2,000,000
Middlesex and Dover Oil and Gas Co., Ltd.	Toronto	Feb. 7	2,000,000
Mikado Consolidated Mines, Limited	Kenora	Nov. 16	5,000,000
Mono Petroleum Products, Limited	Toronto	May 25	500,000
Montreal-Kirkland Mines, Limited	Kirkland Lake	Nov. 16	2,500,000
Mount Eagle Feldspar Company, Limited	Toronto	Mar. 21	1,000,000
Muir Porcupine Gold Mining Company, Limited	Toronto	May 9	2,000,000
North Trail Gold Mines, Limited	Toronto	Aug. 13	2,000,000
Noyes Mining Company, Limited	Peterborough	Nov. 14	1,000,000
Porcupine Davidson Gold Mines, Limited	Toronto	Aug. 18	(£) 1,000,000
Porcupine Peninsular Gold Mines, Limited	Toronto	July 25	1,000,000
Porter Gold Mines, Limited	Toronto	Sept. 2	2,500,000
Queen Lebel Gold Mines, Limited	Kitchener	May 27	2,000,000
Queenston Quarries, Limited	St. David	Mar. 8	250,000
Rendix Mines, Limited	Toronto	Mar. 5	1,000,000
Ribble Mines, Limited	Toronto	Nov. 24	2,000,000
Royal-Flush Oil and Gas Company, Limited	Toronto	Feb. 9	500,000
St. Anthony Gold Mines, Limited	Toronto	Sept. 9	3,000,000
Sanderson-Kirkland Gold Mines, Ltd.	Toronto	May 30	2,500,000
South Keora Mines, Limited	Toronto	April 14	3,000,000
Storrington Feldspar Company, Limited	Kingston	May 10	100,000
Sydenham-St. Vincent Oil and Gas Co., Ltd.	Owen Sound	Aug. 15	40,000
The American Matachewan Gold Mining Co., Ltd.	Toronto	April 19	1,000,000
The Arkona Gas and Oil Company, Limited	Toronto	May 16	300,000
The Asbestos Pulp Company, Limited	Belleville	Jan. 18	200,000
The Dominion Petroleum Company, Limited	London	May 25	100,000
The Gold Nugget Mining and Development Co., Limited	Sudbury	April 21	500,000
The Grenville Crushed Rock Co., Ltd.	Smiths Falls	Jan. 5	300,000
The McEnaney Gold Mines, Limited	Toronto	Aug. 12	3,000,000

MINING COMPANIES INCORPORATED IN 1921—*Continued*

Name of Company	Head Office	Date of Incorporation	Capital
Toronto-Grey Gas and Oil Company, Limited	Toronto	April 18	\$ 600,000
Triplex Gold Mines, Limited	Toronto	June 1	5,000,000
Two-in-One Gold Mines, Limited	Toronto	April 7	5,000,000
Wentworth Oil and Gas Company, Limited	Hamilton	Jan. 19	100,000
West Beaumont Gold Mines, Limited	Toronto	Feb. 26	2,000,000
Total (67 Companies)			105,715,000

Companies of Extra-Provincial incorporation holding mining lands in Ontario are required under The Ontario Companies Act, to take out a license and specify the amount of capital used in Ontario in connection with mining.

Following is a list of the Companies so licensed in 1921:

MINING COMPANIES LICENSED IN 1921.

Name of Company	Head Office for Ontario	Date of License	Capital for use in Ontario
Consolidated Molybdenum Steel Corporation, Ltd.	Renfrew	Mar. 22	\$ 500,000
Dickson Creek (Cobalt) Silver Mines, Limited	Haileybury	Jan. 5	100,000
Empire Asbestos Mines Company, Limited	Toronto	May 11	40,000
Hamilton-Bothwell Oil Company, Limited	Hamilton	Jan. 18	300,000
The Eureka Flint and Spar Company, Limited	Kingston	Feb. 24	40,000
Wheeling Feldspar Company, Limited	Burks Falls	Feb. 9	50,000
Total (6 Companies)			1,030,000

Companies which surrendered their charters were as follows:

MINING COMPANY CHARTERS SURRENDERED IN 1921.

Name of Company	Date of Dissolution
British American Metal Company, Limited	Mar. 21
Burlington Steel Company, Limited	Mar. 21
Indian Peninsula Mining Company, Limited	Feb. 14
Petrol Oil and Gas Company, Limited	Feb. 21
The Smiths Falls Malleable Castings Company, Limited	Jan. 31

Provincial Assay Office

The Provincial Assayer, W. K. McNeill, reports as follows for the year 1921:

The Assay Office has been in operation without interruption during the entire year, and the usual variety of work has been done with the assistance of T. E. Rothwell, Chemist and Assayer, and Robert Stewart, Laboratory Assistant.

The work during the year may be classified as follows:

Gold, Silver and Platinum.—1,019 samples were tested and reports issued.

Cobalt and Nickel.—9 samples were tested and reports issued.

Copper.—25 samples. These were mainly from Ontario.

Feldspar.—9 samples were submitted for complete analysis.

Iron Ores.—28 samples were received. A number of these were analyzed for sulphur and phosphorus.

Rocks.—11 samples were received for complete analysis. These were submitted by the geologists of the Department of Mines.

Radium.—68 samples were tested for radio-activity. These were from widely distributed sources, but mainly from Parry Sound and Eastern Ontario.

A large number of samples were brought directly to the Laboratory and if not radio-active, no record is kept.

Identification.—152 samples were sent to the Laboratory for identification. Many more were brought direct to the office. Of these latter no record is kept.

Miscellaneous.—71 samples of other minerals were tested. These included lead, zinc, tin, barite, etc. A large number of samples of water were brought to the laboratory to be tested for oil.

Following is a statement of samples assayed free when accompanied by coupons issued by Mining Recorders under the provisions of the Mining Act of Ontario:

Mining Division	Samples received for Free Assay.
Kenora.....	8 samples for gold, 4 silver, 1 lead.
Fort Frances.....	5 samples for gold, 1 silver, 2 copper, 1 zinc, 2 nickel.
Kowkash.....	3 samples for gold.
Parry Sound.....	1 sample for silver.
Sault Ste. Marie.....	38 samples for gold, 5 silver, 2 iron, 3 copper, 1 tin.
Sudbury.....	55 samples for gold, 18 silver, 7 copper, 4 lead, 1 platinum.
Timiskaming.....	28 samples for gold, 18 silver, 2 copper.
Montreal River.....	39 samples for gold, 2 silver.
Porcupine.....	66 samples for gold, 4 silver, 3 nickel.
Gowganda.....	13 samples for gold, 4 silver.
Port Arthur.....	45 samples for gold, 7 silver, 1 lead, 10 iron, 2 molybdenum, 1 copper.
Eastern Ontario.....	4 samples for gold, 2 silver.

The schedule of charges for the Provincial Assay Office and Chemical Laboratory is as follows:

TARIFF OF FEES FOR ANALYSES AND ASSAYS.

1. Assays:	
Gold	\$1 50
Silver	1 50
Gold and silver in one sample	2 50
Platinum Minerals	5 00
Gold and Platinum minerals in one sample	7 00
Separation of Platinum Minerals	Prices on application
2. Iron Ores:	
Iron (metallic)	\$1 50
Silica	1 50
Iron and insoluble residue	2 50
Ferrous Oxide	2 00
Phosphorus	3 00
Sulphur	2 50
Iron, Sulphur, Phosphorus and insoluble	8 00
Manganese	3 00
Titanium	4 00
Complete analysis	Price on application.

3. *Limestones, Dolomites, Marls, Clays, Shales:*

Determination of:

Insoluble	\$1 50
Silica	1 50
Ferric Iron	3 00
Ferrous Iron	2 00
Alumina	3 00
Lime	2 00
Magnesia	2 50
Potash	5 00
Soda	5 00
Alkalies (on one sample)	6 00
Water (combined)	2 00
Moisture	1 00
Carbon Dioxide	2 00
Sulphur	2 50
Phosphorus Anhydrite	3 00

4. *Examination of Clay, Shale, or Cement Rock for Cement Manufacture:*

Determination of:

Silica, Iron Oxide, Alumina, Lime, Magnesia, Sulphur, and Volatile matter	Prices on application.
---	------------------------

5. *Coal, Coke, Peat, etc.:*

Determination of:

Moisture	\$1 00
Volatile Combustible	1 50
Fixed Carbon	1 50
Ash	1 50
Sulphur	2 50
Phosphorus	3 00
Caloric value (B.T.U.)	5 00
Ultimate analysis	Price on application.

6. *Mineral Waters* Price on application.7. *Ores and Minerals:*

Determination of:

Alumina	\$3 00
Antimony	4 00
Arsenic	4 00
Bismuth	4 00
Cadmium	4 00
Chromium	5 00
Cobalt	5 00
Nickel	5 00
Cobalt and Nickel on same sample	6 00
Copper	2 00
Fluorite	4 00
Lead	3 00
Molybdenum	4 00
Manganese	3 00
Tin	4 00
Zinc	3 00

8. *Rocks, Complete Analysis* Price on application.9. *Slags, Sand, etc.* Price on application.10. *Identification of Minerals and Rocks not Requiring Chemical Analysis*.....Free11. *Test for Radio-Activity* Free

Any analytical work not specified in this list will be undertaken on application to the Provincial Assayer.

The pulp of each sample is retained for future reference.

DIRECTIONS.

Samples will be dealt with in the order of their arrival. In every instance specimens and samples should be accompanied by statement specifying the precise locality whence they were taken.

Crushed samples representing large quantities or samples less than five pounds weight may be sent by mail as third-class matter. The name and address of sender should be written plainly on each parcel. Instructions, with money in payment of fees, should be contained in a separate letter. Samples may be sent by express, charges prepaid.

Sample bags addressed to this Laboratory for sending ore pulp by mail may be obtained free on application; also canvas bags for shipping.

Money in payment of fees, sent in by registered letter, post-office order, postal note, or express order, and made payable to the Provincial Assayer, must invariably accompany sample to ensure prompt return of certificate, as no examination is commenced until the regulation fee is paid.

Samples should be addressed as follows:

Provincial Assay Office,
5 Queen's Park,
TORONTO, Ont.

Departmental Correspondence

The volume of correspondence necessary for the work of the Department in all its branches is considerable. Figures supplied by the Files Branch show that for the fiscal year ending 31st October, 1921, communications received numbered 22,498, and communications sent out 23,954. New files issued were 650 and amount paid out for postage was \$1,419.

Correspondence in connection with the office of the Minister of Mines is not included, nor is that pertaining to applications for patent or lease of mining lands—the latter files being kept in the Department of Lands and Forests.

GRAVEL DEPOSITS OF THE ST. CLAIR RIVER

By

James Bartlett

In June, 1921, the writer was instructed by Thomas W. Gibson, Deputy Minister of Mines, to investigate the extent of the gravel deposits in the Canadian portion of the Saint Clair river, south of the International Tunnel which joins Sarnia and Port Huron. As the Department of Mines did not wish to have an instrumental survey and borings made this year, the work consisted in ascertaining the approximate positions of the deposits and getting details regarding their magnitude. Six weeks were spent in travelling on the river, locating the positions where gravel boats were dredging and interviewing those likely to have detailed knowledge of the deposits, viz., the officers of some of the gravel companies, the engineers of the Dominion Public Works Department and the masters of the gravel boats. A map was prepared from the information obtained, and it appears as an insert accompanying this report.

Sand and Gravel Definitions and Specifications

The specifications of the Ontario Department of Highways regarding gravel and sand are as follows:

Gravel shall consist of naturally formed fragments of tough, durable rock, well graded in size from the smallest to the largest, free from flat, elongated particles, and shall not contain more than fifteen per cent. by weight of soft, friable material. It shall not contain an excess of clay nor an excess of loose or adhering dust, vegetable loam or other deleterious matter. It shall be satisfactory to the Engineer in all respects.

Run of bank gravel shall be classed according to the following grades:

Grade "A" is a run of bank gravel containing a large percentage of pebbles of igneous rocks. It shall not contain more than 5 per cent. by weight of material which shall be retained on a screen having 4-inch circular openings, and not more than 45 per cent. by weight of material which shall pass a screen having $\frac{1}{4}$ -inch square openings. It shall not contain more than 3 per cent. by weight of clay or loam, nor have a coefficient of wear of less than 14.

Grade "B" is a run of bank gravel containing a smaller percentage of igneous rock pebbles. It shall not contain more than 5 per cent. by weight of material which is retained by a screen having 4-inch circular openings, nor more than 60 per cent. by weight of material passing a screen having $\frac{1}{4}$ -inch square openings. It shall not contain more than 12 per cent. by weight of clay or loam, nor have a coefficient of wear of less than 11.

Grade "C" is a run of bank gravel composed chiefly of pebbles of sedimentary rock. It shall not contain more than 5 per cent. by weight of material which is retained on a screen having 4-inch circular openings, and not more than 80 per cent. by weight of material which passes a screen having $\frac{1}{4}$ -inch square openings. It shall not contain more than 12 per cent. by weight of clay or loam, nor have a coefficient of wear of less than 7.

Grade "D" is a run of bank gravel which does not meet the requirements of any of the above grades, and which may be used only by written permission of the engineer.

Gravel for Gravel Roads.—Gravel is to be clean, moderately coarse and free from an excess of clay, sand or earthy material. The best gravel for roads consists of about 75 or 80 per cent. stone and pebbles, about 10 per cent. coarse sand, and the remainder clay or loam.

Concrete Sand.—Fine aggregate for concrete shall consist of natural sand composed of hard, tough, durable particles graded from fine to coarse. When dry, not more than 6 per cent. shall be retained on a sieve having 4 meshes per lineal inch; not more than 20 per cent. by weight shall pass a sieve having 50 meshes per lineal inch; and not more than 4 per cent. shall pass a sieve having 100 meshes per lineal inch. It shall not contain more than 3 per cent. by weight of clay or loam.

Sand for Bituminous Construction.—Sand for use in bituminous pavement construction shall consist of hard, tough, durable particles. It shall not contain more than one per cent. of clay or loam. The various types of grains present shall be as closely as possible in the following proportions by weight:

Percentage of Sand	Pass	Retained on
30	8-mesh sieve	30-mesh sieve
27	30 " "	50 " "
30	50 " "	80 " "
15	80 " "	100 " "
7	100 " "	200 " "
1	200 " "	...

In Bulletin No. 37, Geological Survey of Georgia, "Preliminary Report on the Sand and Gravel Deposits of Georgia," by L. P. Teas, the following definitions and classifications are given:

Sand consists of fine particles of crushed or worn rock. . . . We may define sand as an incoherent material made up of grains ranging from 1/150th of an inch to 1/4 inch in size. Unconsolidated material whose grains lie between 1/100th and 1/250th of an inch, is known as silt; and if the grains fall below 1/250th of an inch we have clay or mud.

When the grains of any natural, unconsolidated substance become larger than 1/4 inch in diameter, the term gravel is applied to them.

According to Dake¹ the following terms applied to gravel are widely used in Missouri:

Sand.....Through 1/4 inch.
 Torpedo Gravel.....Through 1/4 inch on 1/8 inch, also called Torpedo sand.
 Roofing Gravel.....Through 3/4 inch retained on 1/4 inch.
 Binder Gravel.....Through 1 1/2 inch on 1/4 inch.
 Concrete Gravel.....Through 2 1/2 inch on 1 1/2 inch

Condra² considers three sizes of sand:

Fine Sand.....0.5 mm. or 0.02 inch in diameter.
 Medium Sand.....2.0 mm. or 0.08 " " "
 Coarse Sand.....5.0 mm. or 0.20 " " "

In Memoir 85 of Canada, Geological Survey, "Road Material Surveys in 1914," L. Reinecke, the author says, on page 35:

In the specifications adopted by the American Concrete Institute for concrete highways it is recommended that the coarse aggregate should be such as would pass a 1 1/2-inch round opening and be retained on a screen having 1/4-inch openings; and the fine, that which would pass when dry through a screen with 1/4-inch openings. Not more than 20 per cent. of the fine shall pass a screen having 50 meshes per linear inch, and not more than 5 per cent. a screen having 100 meshes to the linear inch. It is recommended that not over 40 per cent. of the total aggregate used be fine, and that not more than 5 parts of total aggregate be used to 1 of cement. Vegetable matter, loam and clay are a source of weakness in concrete, and the Institute recommends that not more than 3 per cent. of the aggregate should consist of these impurities.

¹ Dake, C. L., The Sand and Gravel Resources of Missouri: Missouri Bureau of Geology and Mines, Volume XV, Page 7, 1918.

² Condra, G. E., Sand and Gravel Resources and Industries of Nebraska: Nebraska Geological Survey, Volume III, Part 1, Page 29, 1908.

Origin of the Deposits

Most of the gravel has been borne by the river from Lake Huron, where it was doubtless obtained from the erosion of the shores which are said to consist largely of glacial deposits. A small percentage of the material may come from streams flowing into the St. Clair river.

No articles have appeared giving the rate at which the east shore of Lake Huron is being eroded, but Leon J. Cole, of Michigan Geological Survey, in an instructive paper on the St. Clair delta, mentions the following with regard to the erosion of the west shore:

That the source of sediments (in the St. Clair delta), is not confined to the east shore of Lake Huron is shown by the work of C. H. Gordon,¹ who studied the destructive action of the waves at a point on the west shore some fifteen miles north of Port Huron. By comparison of surveys made in 1823 and in 1901, Gordon finds that one estate, which contained 184.90 acres at the earlier date, with a water front of something less than a mile, lost in the intervening seventy-nine years, 27.25 acres of land, which was washed away and carried into the lake by wave action—an average of 0.345 acres per annum. The total average recession of the shore line within this area was 449.46 feet, or an average recession of 5.7 feet per annum. The amount of material was 878,944 cubic yards, and it is safe to assume that a great deal of this eventually found its way into the St. Clair river, both on account of the direct wave action along the beach, as on the eastern side, and by the shore currents, which on this side run close to the shore and would catch the lighter materials, that did not sink at once to the bottom. It is important to note the character of the sediments contributed at this place, where the bluff twenty feet in height gives a good section of the glacial deposits which compose the land. According to Gordon the section is made up as follows:

	Feet	Inches
1.—Soil—top loam	1	6
2.—Light coloured or drab Sandy soil, small pebbles.....	9	9
2a—Brownish band: apparently a soil horizon		6
3.—Blue clay; more compact than No. 2a.....	7	0
4.—Blue clay; darker and more compact than No. 3.....	4	0

The gravel deposits are found at intervals in the river, from Lake Huron to the channels emptying into Lake St. Clair. As a rule they occur in the form of long and comparatively narrow bars whose longer axes are parallel to the direction of flow. The current of the river is estimated to be $4\frac{1}{2}$ miles per hour and less, its greatest velocity being at Point Edward. The lessening of the current, when Lake St. Clair is reached, has resulted in the precipitation of large quantities of silt and clay and the formation of the St. Clair delta. As might be expected, the coarser gravel is found in the upper reaches of the river, the pebbles becoming smaller and fewer and the sand more abundant as the river is followed south, until in the vicinity of Algonac the deposits consist either of "torpedo" gravel or of sand.

In the journey down stream the coarser particles roll along the bottom and the lighter sediments are suspended in the water. Divers report that opposite Point Edward their work is at times rendered difficult by the bombardment of pebbles carried by the current and suspended in the water. In times of storms, particularly with winds blowing from a northerly direction, the amount of material swept from the lake into the river at Point Edward is greatly increased. The movement of vessels, especially the large freight boats drawing up to twenty feet of water, exerts a considerable influence in assisting the gravel down stream. Ice and wave action also probably assist to some extent.

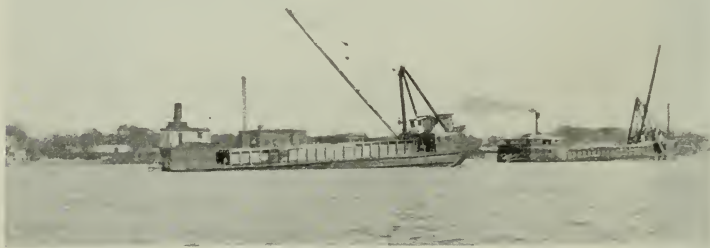
There is but little gravel digging being done this summer in the United States portion of the St. Clair river. Whether this is due to there being little

¹ Wave Cutting on West Shore of Lake Huron, Sanilac County, Michigan, Report Michigan Geol. Survey for 1901, Lansing, 1902.

gravel left, or whether the deposits are being kept for future use, I was unable to learn, but the difficulty of dealing with the owners of the riparian rights is probably a deterring factor. The digging of sand and "torpedo" gravel is practically all being done in United States waters, viz., in the North Channel, the Middle Channel, and Chenal à Bout Rond. It is possible that important deposits of torpedo gravel occur in Canadian water, but little search seems to have been made for them.

Rate of Growth of the Deposits

Opposite Point Edward and Sarnia the deposits shift rapidly; this necessitates frequent surveys by the engineers of the Canadian and United States Governments in the interests of navigation. Dredging is done by both Governments in their respective halves of the river and has been carried on annually for many years. Of late years the shoals in the Canadian portion of the river at these points have been removed by gravel-dredging licensees under the supervision of the engineers of the Dominion Public Works Department. As most



Self-loading Boats Dredging Gravel Below the "Tunnel," St. Clair river

of the material on the two principal deposits, which are known as the "Point Edward" and "Sarnia" shoals, has been of commercial value, the dredging companies are glad to do this dredging free, paying the Province of Ontario royalties on the gravel sold and furnishing certain municipalities in Western Ontario with stipulated quantities of gravel at less than cost.

During 1919, the Point Edward "shoal," which lies beside the Northern Navigation Company's dock at Point Edward, increased by 5 to 7 feet in thickness; in July, 1920, this shoal built up 4 feet at one spot in three weeks. It is the opinion of the engineers of the Public Works Department that the percentage of sand on the Point Edward "shoal" and the Sarnia "middle ground" is increasing. Whereas there used to be plenty of gravel above the 23-foot depth, there is said to be but little to-day. In order that the cross-section of the river may not be increased, and the level of Lake Huron lowered, gravel boats are not permitted to dig to a greater depth than 23 feet in front of Point Edward and Sarnia.

With regard to the rate of increase of the deposits south of the International Tunnel, no exact information is obtainable, but it is generally agreed that the annual increment is small.

The Gravel Boats

To illustrate the size of some of the boats engaged in gravel dredging the following examples are cited:

	Gross tonnage	Net tonnage	Capacity, cubic yards
Str. <i>F. E. Harvey</i>	355	288	340
" <i>C. W. Cadwell</i>	593	212	860
" <i>Chas. Heiden</i>	717	446	625
" <i>John M. McKerchey</i>	443	161	732
Barge <i>Whale</i>	1,144	1,144	1,850
Str. <i>Harsen</i>	...	...	700
" <i>Ontario</i>	...	...	275
" <i>F. C. Osborne</i>	...	...	600

On most of the boats the dredging is done with $11\frac{1}{2}$ cubic yard clams, but in a few cases a $11\frac{1}{4}$ cubic yard size is used. In addition to the clam some of the boats carry a centrifugal pump for winning the gravel. The Str. *John M. McKerchey* has no clam, but is equipped with a Morris centrifugal pump connected to a 10-inch suction; this boat carries a crew of 16 men.



Gravel Boat Leaving Dredge After Being Loaded, St. Clair river

Results of Screen Tests

Eight samples of gravel and sand were obtained from the portions of the river mentioned below, and were sent to the Ontario Highways Department testing laboratory for screen-tests:

- Sample 1—Gravel from Point Edward shoal.
- 2—Gravel from deposit J about $1\frac{1}{4}$ miles north of Sombra village.
- 3—Sand from a cargo dug in the North Channel.
- 4—Gravel from Point Edward.
- 5—"Torpedo gravel" or coarse sand from a cargo dug in the Middle Channel, some four miles below Algonac.
- 6—"Torpedo gravel" dug in U.S. waters in front of Algonac.
- 7—Gravel from deposit 1, which is opposite concession III, township of Moore.
- 8—Gravel from deposit "A" in front of Mueller's Brass Works, Sarnia, and a few hundred feet south of the International Tunnel.

The laboratory tests are given in the Appendix at the end of this report.

Pebbles

As the mineralogical composition of gravels is of importance, I examined the coarser pebbles (roughly $\frac{3}{4}$ -inch and upwards) in the above mentioned samples and found the number and kind of these pebbles to be as follows:

Kind of Rock	No. 1	No. 2	No. 4	No. 6 pebbles over ½-inch	No. 7	No. 8
Limestone.....	43	11	26		34	54
Dolomite.....	21	2	29	1	15	7
Chert.....	12	18	3	2	20	19
Cherty dolomite.....	1		1		2	1
Cherty limestone.....					2	3
Quartzite.....	9	1	5	1	6	7
Arkose.....	3	1	5		2	3
Granite.....	7	2	6		13	7
Greenstone.....	5	1			2	
Granite Gneiss.....	1		1			1
Green Slate.....	1				1	
Diorite.....	1					
Shale.....		4			10	2
Greywacke.....		2		7	6	2
Hornblende syenite.....		1			1	
Syenite.....			7		1	1
Conglomerate.....			2			1
Red quartzite.....			1			
Sandstone.....					6	
Trap.....					1	
Slate.....					1	
Quartz schist.....						1

Selling Prices of the Gravel

Detroit.—The United Fuel and Supply Company is the largest dealer in sand and gravel in Detroit. It obtains gravel from the St. Clair river and also from seven pits within 25 miles of Detroit. This Company's retail price list of July 20, 1921, quotes the following prices per cubic yard on less than car lots:

Sand, river or washed, screened, flat or sharp:			
District 1	District 2	District 3	District 4
\$2.65	\$3.00	\$3.50	\$3.75
Gravel for concrete:			
District 1	District 2	District 3	District 4
\$2.65	\$3.00	\$3.50	\$3.75
Roofing gravel—any district—per ton, \$2.75.			

The boundary of district No. 1, is roughly a mile and a half from the Detroit river. The above prices are subject to a 5 per cent. discount, 30 days.

Windsor.—In Windsor the retail price of sand and gravel in small lots is \$3.50 per cubic yard for all points less than a mile away from the docks; outside the one mile radius the rate is \$3.25. Fifty cents more per yard is charged if the gravel is screened. Algonac "torpedo gravel" sells here for \$3.50 per cubic yard in small lots. The discount in Windsor is 7 per cent., 30 days.

The prevailing practice in both cities is to call material below ¼-inch sand. Most of the sand is sold as "flat" or "sharp." The "flat" sand is fine and suitable for mortar or plaster; the "sharp" is coarse, such as is obtained in the North Channel and near Algonac, and is particularly suitable for the manufacture of concrete blocks.

Details of the Deposits

The map which accompanies this report was compiled from Lake Survey charts and Department of Militia maps. On this the information obtained from those engaged in dredging gravel was plotted, the several deposits being dis-



PROVINCE OF ONTARIO
DEPARTMENT OF MINES

MAP OF THE

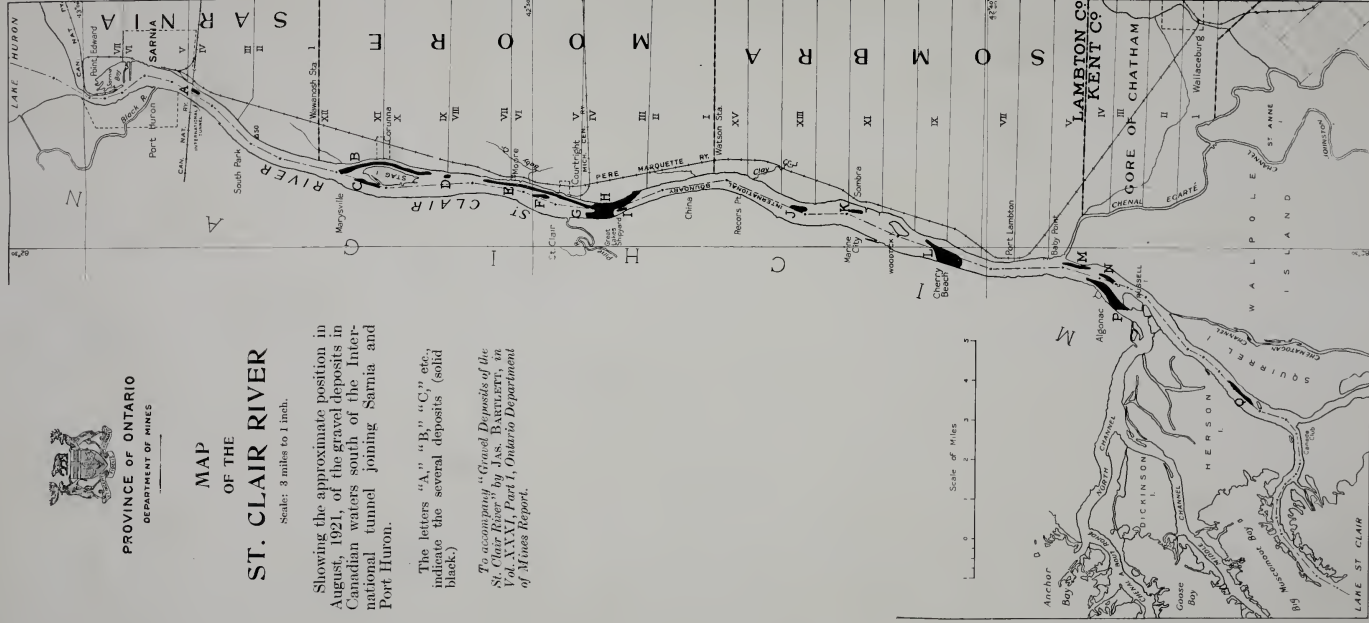
ST. CLAIR RIVER

Scale: 3 miles to 1 inch.

Showing the approximate position in August, 1921, of the gravel deposits in Canadian waters south of the International tunnel joining Sarnia and Port Huron.

The letters "A," "B," "C," etc., indicate the several deposits (solid black.)

To accompany "Gravel Deposits of the St. Clair River" by JAS. BARTLETT, in Vol. XXXI, Part I, Ontario Department of Mines Report.



tinguished by letters. As even those who have been dredging gravel for years do not, as a rule, possess accurate information about the deposits, it necessarily follows that the outlines of the deposits, as shown, are by no means exact. The following notes regarding the deposits are a compilation of the data obtained from various sources:

"A"—In front of Mueller's Brass Works, Sarnia: This deposit is from 40 to 80 feet wide, and extends for 1,000 feet south of the International Tunnel; it is from 3 feet to 6 feet thick, but at some points the underlying clay has been bared. Much of the gravel here was probably dumped from scows engaged in dredging the channel. Sticks and balls of mud are quite numerous in this deposit.

A couple of miles south of the Tunnel and north of Boundary Survey Monument No. 50, there was a four-foot bed of gravel some four years ago.

"B"—East of Stag island. This deposit was at one time five or six feet thick, but is now nearly worked out, and where gravel remains it is rarely more than one bucket, or three feet, in thickness. One captain told me that in getting a load recently from the central part of this bar he had to drop down stream in all 800 feet.

"C"—West of Stag island. This deposit consisted of fairly good gravel, but carried considerable sand. Some uncertainty was expressed as to whether it extends west into deep water or not; one captain states that it was from 2 to 8 feet thick, about 90 feet wide and is now almost exhausted.

"D"—This is a small deposit near Stag Island Lower Light. None of the captains interviewed had dug here of late years.

"E"—Extends from a mile north of Moore to south to Courtright. This bar was formerly from 2 feet to 8 feet in thickness, with an average of about 6 feet and was about 250 feet in width. Most of this deposit is now worked out, particularly that portion which lies above Courtright.

"F"—Is situated west of Deposit "E" and east of the St Clair Middle Ground. It is said to have been at one time 14 or 15 feet thick, but is now nearly depleted.

"G"—Is a deposit in U.S. waters whose dimensions I did not learn. It is said to extend from above the town of St. Clair to the Great Lakes shipyard.

"H"—Is an extension of "E" to the south. This was one of the largest deposits in the river and consisted of a fairly coarse gravel up to 12 feet in thickness. It is now said to be from 0 to 4 feet thick.

"I"—Is a small deposit in U.S. waters south of the Great Lakes shipyard. This consists of coarse gravel and is about 40 feet wide, and 4 or 5 feet thick. The material in Canadian water east of this point in "H" deposit is considerably finer.

"J"—Is opposite concession XIII, Sombra township. This is said to have been from 8 to 10 feet thick and some 800 feet in width. One captain stated that it probably had been 20 feet thick at the International Boundary. Considerable digging was still being done on this deposit this summer.

"K"—Is a small deposit in front of Sombra village. It is practically worked out, but was formerly 1,000 feet long and up to 6 feet thick.

"L"—Is south of Woodtick island. A great deal of gravel was dug from this deposit in past years, but not a boat was seen loading here during my stay. The gravel was said to have been 8 or 10 feet thick in the Canadian portion and some may still remain, but the U.S. portion is believed to be about exhausted.

"M"—This bar, south of the head of the *Chenal Écarté*, consists of sand and "torpedo gravel" with the former predominating. The thickness is not known.

"N"—Is south of "M" and northeast of Russell island. It is said to be 8 or 9 feet thick, and to consist largely of "torpedo gravel."

"P"—Is in front of Algonac and consists of sand and "torpedo gravel." It is said to be getting thin.

"Q"—Is situated about three miles north of the Canada Club. It consists of "flat" (plaster) sand and it is stated that a load can be pumped at any point on the deposit without changing the boat's position.

From Algonac to Lake St. Clair, via the North Channel, large deposits of "torpedo gravel" and of sand are reported. Sand is also dug in the Channel known as the Baltimore Highway. The bed of the Middle Channel is said to be covered with sand throughout most of its course.

Gravel Tests

Mr. H. E. Davis, Testing Engineer, Department of Public Highways, under date of September 14th, 1921, reported to the Department of Mines on the eight samples of gravel submitted, as follows:

In accordance with your request regarding samples of gravel submitted for test, I am attaching copies of Reports giving the granulometric analysis, and ratio of sand to gravel. The colorimetric test was satisfactory in all cases.

All of these samples would be considered suitable aggregates for concrete work. It will be noted, however, that in the case of sample No. 3, there is no gravel present and for making satisfactory concrete this addition would have to be made. The silt and organic matter apparently has been washed free from all eight samples.

For convenience these separate reports have been arranged in tabular form.

Mechanical Analysis	Sample No.							
	1	2	3	4	5	6	7	8
SAND—								
Percentage retained on								
10 mesh screen.....	30.0	37.4	1.0	46.4	43.4	48.8	40.4	57.4
20 " ".....	63.0	44.0	6.0	75.4	61.6	65.4	51.8	73.0
30 " ".....	84.0	47.8	18.0	89.0	69.6	71.0	57.8	80.0
40 " ".....	93.0	53.2	38.8	95.0	78.0	76.0	65.0	86.6
50 " ".....	97.0	66.2	66.4	98.8	90.4	85.2	75.6	92.4
100 " ".....	99.0	97.2	96.0	99.8	99.0	99.2	96.8	99.0
200 " ".....	99.6	99.8	99.6	99.9	99.9	99.9	99.2	99.6
GRAVEL—								
Percentage retained on								
1-1/4 inch screen.....	14.2			10.6			13.5	2.5
7/8 " ".....	18.2			14.5			23.6	10.0
3/4 " ".....	27.5	1.2		19.9	0.9		33.5	21.7
1/2 " ".....	38.0	8.9		42.4	1.9	0.6	50.0	39.7
1/4 " ".....	53.0	30.3		63.1	9.0	11.9	72.2	64.2
PERCENTAGE RATIO:								
Sand.....	47	69.7		36.9	91	88.1	27.8	35.8
Gravel.....	53	30.3		63.1	9	11.9	72.2	64.2

Future Demand for the Gravel

As Essex, Kent and Lambton counties contain but few gravel pits and very few rock outcrops, there is a constant and increasing demand for river gravel for road building and general construction work. There is no doubt that this demand will continue to increase, as the building of good roads in these counties has been under way for comparatively few years.

Conclusions

The following conclusions have been reached regarding the gravel deposits south of the Tunnel:

1. That the deposits are being rapidly depleted and that many of them are worked out or the gravel remaining is so thin that digging is no longer profitable.
2. That the annual increment south of the Tunnel is comparatively small.
3. That there are probably some, but not many, deposits which have not been found.
4. That no estimate can be made as to how much longer digging can be carried on at the present rate unless a hydrographic survey be made and borings put down at frequent intervals. I do not believe that the deposits warrant the expenditure.

Acknowledgments

I wish to express my appreciation of the courtesies shown me and the assistance given by Messrs. H. B. R. Craig and John Graham, engineers of the Public Works Department, the officers of the United Fuel Company and the Chick Contracting Company, and particularly by Mr. Thos. W. Whiteley, inspector of dredging operations for the Ontario Department of Mines.

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Page 43, line 13, *for* "in the pocket at the back of the report," *read* "in the separate map case accompanying this report."

Page 52, line 3, *ditto*.

Page 93, line 24, *ditto*.

Page 179, line 17, *ditto*.

Page 196, line 5, *ditto*. Line 17, *for* "pocket" *read* "map case".

Pages 241 to 318, *for* "mining" in title and running heading *read* "milling".



PROVINCE OF ONTARIO
DEPARTMENT OF MINES

HON. CHARLES MCCREA, MINISTER OF MINES

THOS. W. GIBSON, DEPUTY MINISTER

THIRTY-FIRST ANNUAL REPORT
OF THE
ONTARIO DEPARTMENT OF MINES
BEING

VOL. XXXI, PART II, 1922

Geology of the Mine Workings of
**Cobalt and South Lorrain
Silver Areas**

By
Cyril W. Knight

Together with a Description of
**Milling and Metallurgical Practice in Treatment
of Silver Ores at Cobalt**

By
Fraser D. Reid, James J. Denny and R. H. Hutchison

PRINTED BY ORDER OF THE LEGISLATIVE ASSEMBLY OF ONTARIO

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1924



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"The ore is undoubtedly very rich, containing values in nickel, cobalt, silver, and arsenic, and a comparatively small vein could be worked at a handsome profit".—Willet G. Miller in the *Engineering and Mining Journal*, December 10th, 1903.



Fig. 1—Map showing the location of Cobalt in relation to the other important mining areas of northeastern Ontario, namely, Sudbury, Porcupine, Kirkland Lake, South Lorrain, and Gowganda.

AUTHOR'S PREFACE

In preparing this report the main object in view was to construct geological plans of all the mine workings in Cobalt and South Lorrain, and to put on record a brief description of the geology of these workings. This object has been, for the most part, accomplished; unfortunately a few of the mines were idle or flooded, hence no examination could be made of these properties.

The report may perhaps be regarded as supplementary in character to Dr. Willet G. Miller's well-known work on Cobalt, the last edition of which was published in 1913 in Volume XIX, part 2, of the Ontario Bureau of Mines Annual Reports. There still remain on hand copies of his report together with geological maps of the surface. For those who are not already familiar with the general geology of the camp, Miller's memoir should be read in conjunction with the present one.

In the year 1919 the mine managers of Cobalt requested the Ontario Department of Mines to undertake a detailed geological survey of the mine workings. The department acceded to their request, and the preparation and publication of this report were undertaken. If the report serves any useful purpose, it will be largely due to the mine managers who made possible the carrying out of the work. The writer wishes to acknowledge their co-operation and to thank them heartily for the many courtesies, social and otherwise, which were extended to him. Those who know Cobalt are familiar with the spirit of hospitality which exists there among mining men.

Messrs. Fraser D. Reid, J. J. Denny, and R. H. Hutchison have written the section of the report dealing with the milling and metallurgical practice in the treatment of silver ores at Cobalt. The preparation of their report entailed much arduous labour—given ungrudgingly and without remuneration of any kind. For them it was an unselfish piece of work done for the love and advancement of the science of milling and metallurgy. There are too few instances of such service for the public good. The Ontario Department of Mines and many engineers owe Messrs. Reid, Denny, and Hutchison a debt which will not be easily paid. The writer thanks them sincerely for their kindness in preparing the report.

To Mr. Thomas W. Gibson, Deputy Minister of Mines, the writer expresses his thanks not only for the sympathetic attitude which he took towards the work, but especially for his steady support in the way of procuring the appropriations which made it possible. The report has cost more than any other of its kind ever published by the Ontario Department of Mines. This cost was largely due to the expense of publishing the accompanying maps and cross-sections.

Cobalt was discovered in the summer of 1903, and in the fall of that year W. G. Miller began his geological work in the newly-found camp. Since the early spring of 1904 the author has assisted Dr. Miller in his labours in the Cobalt silver field. As a student prior to that time, the author gained his first knowledge and love of the science of geology from Dr. Miller who, before he became Provincial Geologist for Ontario, was professor of geology at Queen's University, Kingston. To all his old students Dr. Miller has, indeed, been guide, counsellor, and friend. This opportunity is taken to thank him for the many years of inspiring companionship and of unstinted advice.

During the course of the work Messrs. James Hill, T. R. Buchanan, J. M. Robb, and David Hill acted as valuable assistants. Acknowledgment is herewith made of their help. Mr. James Hill has, moreover, read and corrected much of the proof of the report.

Miss D. J. Ferrier has also very kindly read many pages of the proof.

Mr. W. K. McNeill, Provincial Assayer for the Province of Ontario, and Mr. T. E. Rothwell have kindly made the analyses which were necessary.

The department is indebted to a number of mining engineers who very kindly undertook to write an account of the discovery and early history of certain mines. Mr. Charles A. Richardson has given an interesting account of how the Temiskaming mine was discovered, and Mr. Norman R. Fisher has written concerning the early mining operations at this property. Mr. Walter E. Segsworth, who was largely responsible for the discovery of the Seneca-Superior, and who was its managing director, has furnished the department with an excellent report concerning the geology and history of that mine. Mr. Balmer Neilly has also written a description of the Penn-Canadian mine, and Mr. R. W. Brigstocke an account of the Drummond mine. In South Lorrain, Mr. Horace Strong kindly wrote the history of the Frontier mine, prior to its acquisition by the Mining Corporation of Canada, Limited.

The writer had the privilege of using an unpublished report dealing with the underground geology of Cobalt. This report, which was written by Alfred R. Whitman, was a private report, made for certain of the mine managers of Cobalt. A summary of Whitman's work appears in Chapter V.

Mr. W. R. Rogers, Statistician of the Ontario Department of Mines, has had the arduous task of compiling the figures showing the production of every mine in the entire Cobalt silver area.

The annual reports of the inspectors of mines for the Province of Ontario have been freely drawn on for information, particularly pertaining to the South Lorrain area. These reports will be found invaluable, especially to those desiring information concerning properties closed down and flooded. In the early days Mr. E. T. Corkill inspected the mines in the Cobalt camp. In later years Mr. T. F. Sutherland was appointed Chief Inspector of Mines. His reports, together with those of James Bartlett, J. G. McMillan, and E. A. Collins, inspectors of mines, give excellent accounts of the progress made from year to year at the various mines and prospects. Their reports also at times touch on the geology of the ore deposits and on the rock structures.

Finally the writer would like to make mention of the mining paper, published in Cobalt, called the *Northern Miner*. This robust little weekly is doing splendid work in promoting not only the interests of silver mining in the Cobalt area, but of mining generally throughout central Canada. It may be added that the *Nugget*, published in North Bay, is doing equally good work in furthering the mining industry.

C. W. K.

Toronto, April, 1924.

OUTLINE OF THE REPORT

The report deals with (1) that part of the Cobalt silver area surrounding and near the town of Cobalt, and (2) one of the outlying areas, namely, South Lorrain (Fig. 45). The area surrounding and near the town of Cobalt has produced 96 per cent. of the total output of silver from all parts of the field.

The report is divided into five chapters. The first chapter discusses the recent discoveries of ore-bodies; the total production of silver, cobalt, nickel, and arsenic in the entire camp including Cobalt, South Lorrain, Gowganda, and the other outlying areas; certain ideas regarding the deposition of the silver ores; the veins, faults, and so forth. A brief summary of the general geology of the camp will be found in this chapter.

Chapter II gives a detailed geological description of most of the mine workings in the area surrounding and near the town of Cobalt.

Chapter III deals with South Lorrain. It gives a history of that interesting camp, together with an account of the general geology, the ore deposits, and a detailed description of the mine workings.

Chapter IV treats of the mining and metallurgical practice at Cobalt. This section is written by Messrs. Fraser D. Reid, J. J. Denny, and R. H. Hutchison.

In Chapter V will be found a list of the reports and papers which have been published on the geology and mineralogy. A summary of many of these papers is given.



Fig. 2—McKinley-Darragh mine, Cobalt, showing stope in Cobalt lake fault, 350-ft. level. The fault is a reverse type with a displacement of about 550 feet at the McKinley-Darragh. The ore-shoot mined from this stope yielded about half a million ounces of silver.

CHAPTER I

INTRODUCTION

The rocks of the Cobalt silver field, as mining men now know, belong to that much discussed pre-Cambrian shield which stretches westward from the Atlantic ocean about three-quarters of the way across Canada. This immense region has of recent years been much written about in the annual reports of the great banking institutions of Canada, in the financial press, in the technical journals, and in daily newspapers which devote space to the mining industry. The eyes of a great part of the mining world are turned more and more towards this great prospective source of wealth. As a result the general public is commencing to get a faint inkling regarding its relation to the prosperity of Canada. In recent months it has, indeed, been the subject of a lively and prolonged controversy regarding its ultimate production of economic minerals. Although it may not, perhaps, be the province of this report to take any part in that controversy, nevertheless the writer cannot refrain from stating his belief, a belief held by most mining men, that there will be found untold riches in the pre-Cambrian shield as years go by. Including the great iron and copper mines in the Lake Superior region, the nickel of Sudbury, the silver of Cobalt, and the gold of Porcupine and of Kirkland Lake, the region has produced wealth amounting to many billions of dollars.

The writer may perhaps be pardoned for again alluding to the pre-Cambrian shield as he has done in the preceding paragraph. To some mining men in Ontario and elsewhere these remarks are now trite and commonplace. Government reports on mining subjects, however, often circulate into the farthest corners of the earth, and this report may, perhaps, tell the story of the pre-Cambrian to some who have not yet heard it. If the above remarks will serve in even a remote way to increase the stream of capital for mining purposes which is flowing towards Canada, particularly Ontario, the repetition will surely be justified.

Among the great silver fields of the world, Cobalt is only exceeded in silver production by the following three historic camps: Potosi in Bolivia, with a production of 30,000 metric tons of silver; Guanajuato in Mexico, with 15,000 metric tons; and Zacatecas in Mexico, with a production of 14,000 metric tons. Cobalt yielded 10,375 metric tons to the end of the year 1922. To the end of the year 1923, Cobalt produced a total of 343,895,780 troy ounces of silver.

In addition to this, to the end of the year 1922, Cobalt yielded \$10,606,880 in cobalt and its compounds, \$764,976 in nickel and its compounds, and \$3,541,491 in arsenic and its compounds.

These figures regarding the production from the Cobalt field include Cobalt and all the outlying areas.

The amount of dividends compared with the quantity of silver produced is very large. The Nipissing, as the late Mr. R. B. Watson pointed out, has paid to its stockholders in dividends 66 per cent. of all the money received by the Company.

The most striking development in the Cobalt silver field in the past two years has been the discovery of high-grade ore in South Lorrain at the Keeley

and Frontier mines. This has been the means of renewing a more general interest in silver mining. The promising development, too, at the Colonial and Genesee mines in the fall of 1923, has been a cheering influence. And the discovery of a strong vein of cobalt ore, containing small patches of high-grade silver, under a drift-covered area at the Ruby has raised hopes in that section.

These recent discoveries, combined with the fact that the silver-bearing rocks extend across a stretch of country, not yet intensively prospected, at least 70 miles long (Fig. 44) appear to justify the belief that mining of silver will continue to be carried on somewhere in this area for many years to come. In the words of Mr. R. B. Watson, "It takes a long time for a good camp to die."

In a mining way the most interesting development of recent years has been the treatment of great quantities of low-grade ore. The Coniagas, for instance, in the last two years has been milling ore which averaged only between eight and ten ounces of silver per ton. The stopes throughout the camp have been



Fig. 3—Railway station at Cobalt, 1922.

mined to much greater widths than was the case in the early days when only high-grade ore was extracted. The ore in these wide stopes—in one case over 80 feet in width—consists of country rock which has been mineralized along tiny cracks with thin leaves of native silver or other silver ores.

It is not the province of this report to publish again a full account of the general geology of the Cobalt silver area. That has already been done years ago by Miller. But a brief summary of the geology may be found useful for those who do not happen to have a copy of Miller's report at hand. It will be recalled that the silver deposits are associated with a great sheet of diabase a thousand feet thick. This sheet penetrates beds of sedimentary rocks consisting of conglomerate, quartzite, and greywacké. The sediments rest on Keewatin basalt; the diabase sheet also penetrates the Keewatin. The deposits consist of narrow, generally vertical veins, averaging three or four inches wide, cutting the sediments, the diabase sheet, and the Keewatin. The silver occurs chiefly in the native form. A fuller summary of the general geology will be found elsewhere in this report.

In connection with our knowledge of the veins there have been two outstanding developments in the last decade. The first of these developments has been the gradual realization that most of the silver in Cobalt occurs at the base of the sedimentary rocks, the Cobalt series, immediately above the Keewatin rocks (Fig. 5). This contact has proved to be the most productive ore horizon in the camp. The depth of this contact zone is, indeed, shallow—between 100 and 200 feet above the contact between the Keewatin and Cobalt series.

The second outstanding development is the recognition that faults appear to have played an important part in the formation of some of the ore shoots. That is to say, certain faults, older than the ore bodies, appear to have acted as barriers or “dams” by confining the deposition of the silver ores within certain restricted areas. The Beaver-Temiskaming ore shoots, for example, are terminated at the north end by a fault.

The recognition of deep-seated, pre-glacial weathering by J. Mackintosh Bell at the Keeley mine in South Lorrain has been a notable feature.

Another point of interest regarding the ore-bodies is the growing belief among geologists that the veins are, in part at any rate, replacement types. That is to say, the mineral-bearing solutions have found their way along joints and faults and have replaced the wall rocks as deposition took place. Open fissures are believed to have been uncommon.

Of interest, too, is Mr. J. E. Spurr's recent announcement of his belief that the veins of Cobalt belong to a class of deposits which he has named *vein dikes*.

Our knowledge of the number and location of the veins has increased in recent years on account of the great amount of development work which has been carried on. Mining operations have revealed an amazing net-work of veins, the intricacy of which is shown on plan No. 31a. Many of these veins do not outcrop on the surface and hence the early maps do not show all the ore-bodies. The plan brings out the fact that the veins are found in what have been called by mining men in Cobalt *vein-systems*. These vein-systems occur in a somewhat isolated manner separated by barren areas. Examples of some of the vein-systems are the Beaver-Temiskaming, the Kerr Lake-Crown Reserve, the Meyer-Coniagas-Trethewey system, and so on.

The faults in the area around the town of Cobalt have now for the first time been mapped. It has been found that pay ore occurs in some of these faults, including the greatest in the camp, namely the Cobalt lake fault.

Area Covered by Report

The Cobalt silver area includes a number of silver-producing localities occurring across a stretch of country 70 miles in length, from the southeast to the northwest (Fig. 45). Chief among these is the Cobalt area proper which comprises the locality surrounding and near the town of Cobalt; this area of about five square miles has produced 96 per cent. of the entire production to the end of the year 1922. Next in point of interest, at the moment, is South Lorrain, about 16 miles southeast of the town of Cobalt, which has produced 1.4 per cent. of the entire production to the end of the same year.

It is with these two localities, the area around and near the town of Cobalt and the South Lorrain area, that this report deals. Statistics, however, referring to the entire camp, including Cobalt and the outlying areas, are given.

Descriptions of the other areas, namely, Gowganda, Casey township, Cane and Auld, Shining Tree, Maple Mountain, Bay Lake, and Wendigo, will be found in Dr. Miller's report referred to in the Preface. An excellent report was

also made on Gowganda by A. G. Burrows, the fourth edition of which was published in the thirtieth annual report of the Ontario Department of Mines in the year 1920.

When Work Was Done

The work of examining the mines was begun in the spring of 1920, during which year five months were spent in a detailed geological survey. In 1921, seven months were similarly devoted to the task; while in 1922, one month was spent mostly in South Lorrain. In the spring of 1923, about two weeks were devoted largely to the examination of certain properties which had become accessible in the meantime, namely, the Seneca, La Rose Extension, Genesee, Ruby, and the deep shaft on the Colonial. During the latter part of January, 1923, a brief visit was paid to the Keeley mine, for the purpose of photographing vein No. 26 which developed an extraordinary width of high-grade ore at one place (Fig. 50).

Preliminary Report

As the work had extended over a period of about three years' time it was thought desirable to issue a preliminary report. This report, under the title "Cobalt—Its Past and Future," was published on May 6th, 1922, in the Engineering and Mining Journal-Press of New York. In August of the following summer, 1923, the complete report on South Lorrain was published as Bulletin No. 48 of the Ontario Department of Mines. This forms Chapter III of the present report. At the same time that this bulletin was published, the report on the milling and metallurgical practice at Cobalt, by Messrs. Reid, Denny, and Hutchison, was issued as Bulletin No. 47. This is Chapter IV of the present report. In publishing these parts separately before the entire report could be issued, the department acceded to a demand from certain quarters to give some sort of preliminary statement prior to the publication of the final report. These separate reports made it less urgent to hurry the publication of the final report.

It may be added that when the writer first undertook the work, and during its early progress, it was sometimes remarked to him, by certain individuals, that the report would be largely of the nature of a *post mortem*. The work was begun several months before the important discoveries were made in South Lorrain at the Keeley and Frontier mines. These discoveries in South Lorrain have proved that the *post-mortem* report on the Cobalt silver camp may not be written in our generation, and probably not, let us believe, for many years to come. The recent utterances of certain well-known mining men confirm this view.

Maps Accompanying Report

In the map case accompanying this report will be found a set of geological plans. These plans represent in a detailed manner the geology of practically all of the mine levels in Cobalt and South Lorrain. They show the kinds of rocks, the veins, the faults, and the position of the drifts, crosscuts, shafts, and so forth. No such complete set of geological plans showing the mine workings has been published of any of the other important mining camps in Canada; and there are few camps in the United States which have had published similar geological plans of all the levels. The Comstock lode in Nevada is an outstanding exception.

The plans show only one vein in the drifts, the veins being indicated by a red line. It may be pointed out, however, that in many places there may be

two or more parallel veins in the same drift, but on the small scale on which the plans are published it was not possible to show the vein systems in all their complexity.

The drawing and preparation of the plans and sections was accomplished mainly by Mr. A. Braidwood. Mr. H. C. Smith also did much of this work. The task of reducing and compiling the hundreds of mine level plans to a uniform scale required some two years of painstaking labour, and Messrs. Braidwood and Smith are to be complimented on the excellent character of their work.

As the report deals essentially with the underground geology it was not thought advisable, on account of the added expense, to reprint all of the geological surface maps which accompany Miller's report. Only one of these surface maps accompanies the present report on Cobalt. These surface maps are still in print and may be obtained, together with Miller's report, from the Ontario Department of Mines, Toronto. That on a scale of 400 feet to the inch will be found especially useful. In the case of South Lorrain, however, a new detailed surface map showing the geology and contours of the productive part of the area will be found in the map case accompanying the report. There is also a reprint of part of A. G. Burrows' plan of South Lorrain, scale one mile to the inch.

THE ORES AND HOW THEY OCCUR

Grade of Ore.—As is well known among mining men, the silver veins are exceedingly rich, containing from one or two hundred troy ounces of silver to the ton to as high as five or ten thousand ounces. In recent years, however, the wall-rock of these high-grade veins in certain properties around Cobalt lake is being treated, and ore as low as eight to ten ounces per ton is now being mined at a profit. Most of this low-grade ore occurs in rocks of the Cobalt series.

Depth of Ore-Shoots.—The silver from Cobalt has been obtained from a shallow zone, most of the ore having been mined from a depth of not more than about 300 feet.

The greatest depth at which pay ore has been encountered is a little less than 1,000 feet. This ore, which was mostly a good grade of mill-rock, was found at the Colonial mine in the fall of 1923; a comparatively small quantity had been shipped.

A very little silver, some 40,000 ounces, was reported by F. L. Culver to have been mined in the Beaver at a depth of 1,600 feet.

Why the Silver Disappears When Veins Pass from Cobalt Series into Keewatin.—More than 80 per cent. of the silver has been obtained from veins in the Cobalt series. Many of these veins in this series pinch or feather out into stringers on reaching the underlying Keewatin. Veins of this type generally occur in joint planes as distinguished from faults; the fractures were not, apparently, strong enough to pass downward into the tougher Keewatin. The disappearance of silver at the Keewatin contact in veins of this type is thus readily understood.

In the case, however, of veins which persist to unknown depths into the Keewatin, but which lose their silver contents at or near the Keewatin contact, the explanation of the loss of silver at the contact is more difficult. Generally speaking, it is only the stronger fractures, such as faults, which persist into the Keewatin. Vein No. 64 on the Nipissing, for example, occurs in a prominent fault. This vein was explored downward into the Keewatin for 800 feet, but no pay ore was found in the Keewatin although the calcite vein persisted (Fig. 4).

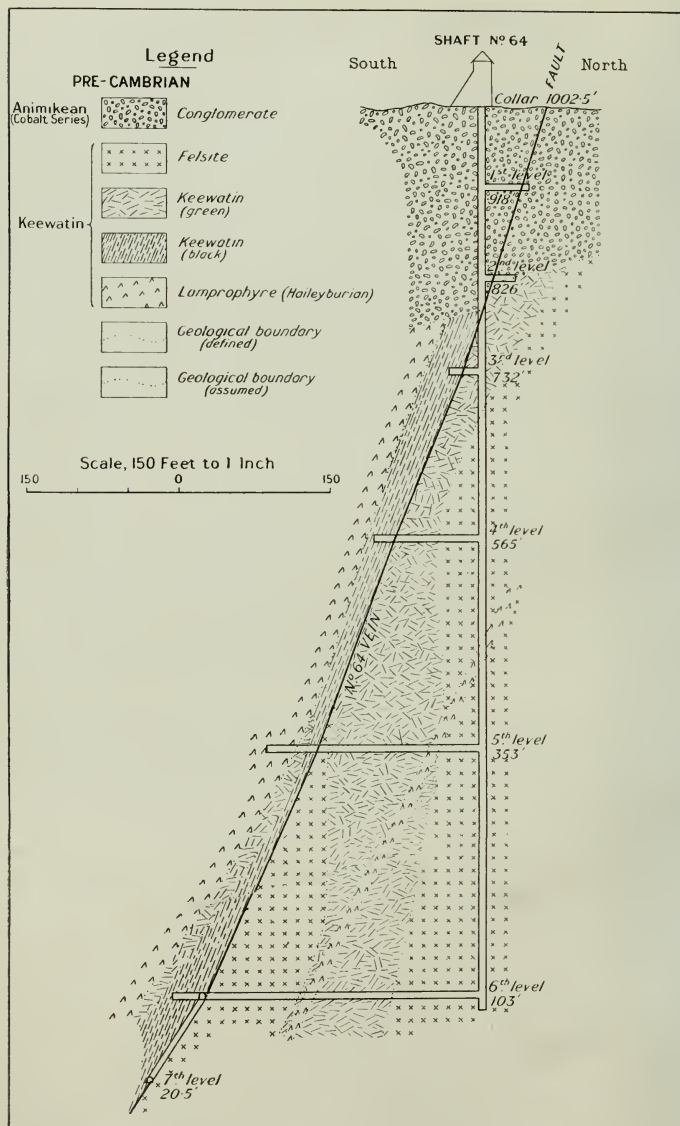


Fig. 4—Vertical section through shaft No. 64, Nipissing mine, showing vein No. 64. This vein occurs in a fault. The vein was productive in the Cobalt series, but no ore was found in the Keewatin rocks below the Cobalt series, although the vein persisted to the bottom of the workings. Section furnished by the Nipissing Mining Company. Elevations are shown in feet above sea level.

Miller explains the disappearance of silver at the Keewatin contact in veins of this class in the following manner.¹

In the case of a vein which passes from the Cobalt series into the Keewatin and carries high silver values in the former and not in the latter, the variation in values is to be accounted for by the fact that there have been two periods of deposition of the ore minerals. The first minerals to be deposited after the cracks were formed were essentially the cobalt-nickel arsenides. After these minerals were deposited there was a slight disturbance of the rocks, and the veins were slightly fractured and opened, giving an opportunity for the deposition of the silver minerals which were then percolating through the rocks. The Cobalt conglomerate and slate-like grey-wacké, being not highly metamorphosed and lying on the Keewatin or in contact with the diabase, were affected by the secondary disturbance, while the great mass of tough Keewatin rock for the most part escaped the disturbance and the veins in it were not fractured so as to give access to the silver solutions.

Relative Quantities of Silver in the Several Rock Series.—Mr. G. R. Mickle in 1912 estimated the relative quantities of silver in the various formations. He found that over 82 per cent. of the silver came from the Cobalt series, 10.85 per cent. from the Keewatin, and 7 per cent. from the Nipissing diabase.²

Ninety Per Cent. of Silver from "Lower Contact".—After twenty years of mining in the Cobalt silver field it is now possible to compare (1) the quantity of silver obtained from the top, or "upper contact" of the Nipissing diabase sill or rocks just above the top, with (2) the quantity of silver obtained from the bottom or "lower contact" of the sill or rocks just below the bottom. And it has been found that by far the greater portion has been obtained from the "lower contact." This contact has, indeed, produced approximately 90 per cent. of the total output, including Cobalt, South Lorrain, Gowganda, Casey township, Montreal River, and Maple Mountain.

The mines which produced their silver from the top of the sill, or upper contact, are the Temiskaming, Beaver, Adanac, Lumsden, Rochester, Nova Scotia, Colonial, King Edward, and Silver Cliff, in the Cobalt area proper; while in South Lorrain and Gowganda all of the output has come from the "upper contact." Every other producing mine of importance in the entire field has yielded its silver from the "lower contact" or rocks just below the lower contact. It may be added that in the fall of 1923 the Colonial mine began to produce a little silver from the lower contact, the previous production from the mine having come from the upper contact. A relatively small, non-commercial quantity of silver was also obtained from the lower contact at the Beaver.

The finding of silver in the deep levels of the O'Brien, Colonial, and Violet workings along the bottom of the Nipissing diabase sill, the "lower contact", opens up a vista of possible ore-shoots which may be contemplated with more satisfaction by the geologist than by the mining engineer. This lower contact extends to the eastward for three and a half miles, and is virgin territory except for a small amount of development work at such properties as the Ruby, Edwards-Wright (Green-Meehan), Agaunico and other mines. But the investigation of this unexplored "lower contact" will require much money, is speculative, and will be looked at with question by mining engineers unless some vein of more or less promise is discovered to lead the way. The veins on the Colonial and Violet are now leading in the direction of the unexplored and unknown. Not far to the east these veins may have to face possible vicissitudes, or enrichments, in the vicinity of the Cross lake fault or branches thereof.

¹Ont. Bur. Mines, Vol. XIX, pt. II, pp. 123-124.

²The Probable Total Production of Silver from the Cobalt District, Jour. Can. Min. Inst., 1912.

Why More Veins in the Cobalt Series than in the Other Rocks.—Most of the veins are found, as already stated, in rocks of the Cobalt series. If the reader will study, for a moment, the coloured cross-section facing page 8 he will obtain some conception of the reason this should be so. The cross-section shows that the Cobalt series forms a comparatively thin stratum of sediments with the great mass of Keewatin below, and the enormous sheet of Nipissing diabase above. The Cobalt series is, indeed, sandwiched between two great igneous masses, which differ from it entirely in character. The Cobalt series is more brittle than either of these masses. If we imagine, then, the three groups of rocks subjected to certain stresses it does not seem unlikely that the more brittle group, the Cobalt series, should develop more fractures than the tougher Keewatin and Nipissing diabase.

It is of interest to add that only at Gowganda has silver been found in the Cobalt series above the Nipissing diabase sill. Mr. A. G. Burrows states that the Millerett in Gowganda produced 500,000 ounces of silver from the Cobalt series above the top of the Nipissing diabase sill.¹

Factors Governing Formation of Silver Ore-Shoots

The ore-shoots in the veins consist of those parts of the veins which contain commercial quantities of silver as contrasted with the barren parts containing calcite and other minerals but no silver. The smallest shoot may be only a few feet in length; the longest, hundreds of feet. The longest shoot is that in the Meyer vein on the Nipissing and Trethewey.

It is of importance to know something about the factors which govern the formation of ore-shoots as distinguished from the barren parts of the veins.

In a broad, general way it may be said that the dominating factor in the deposition of the ore-shoots is the Nipissing diabase sill. Wherever silver ore occurs, there also will be found the Nipissing diabase. No silver ore-shoots occur in the entire camp where the diabase sill is absent.

Next in importance in guiding the deposition of silver ore-shoots appears to be the influence of contacts.

There are three contacts along which the silver ore-shoots have been found. The first and most important contact is that between the Keewatin and Cobalt series. The second contact is that along the bottom of the Nipissing diabase sill. And the third is that along the top of the Nipissing diabase sill.

The contact between the Keewatin and the Cobalt series governs the formation of 80 per cent. of the silver ore. It may be said that all the ore-shoots in the Cobalt series follow along the Keewatin contact and do not rise, as a general rule, more than 100 to 200 feet above the contact. Examples of some of the ore-shoots which occur along this contact are given in following paragraphs.

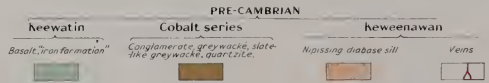
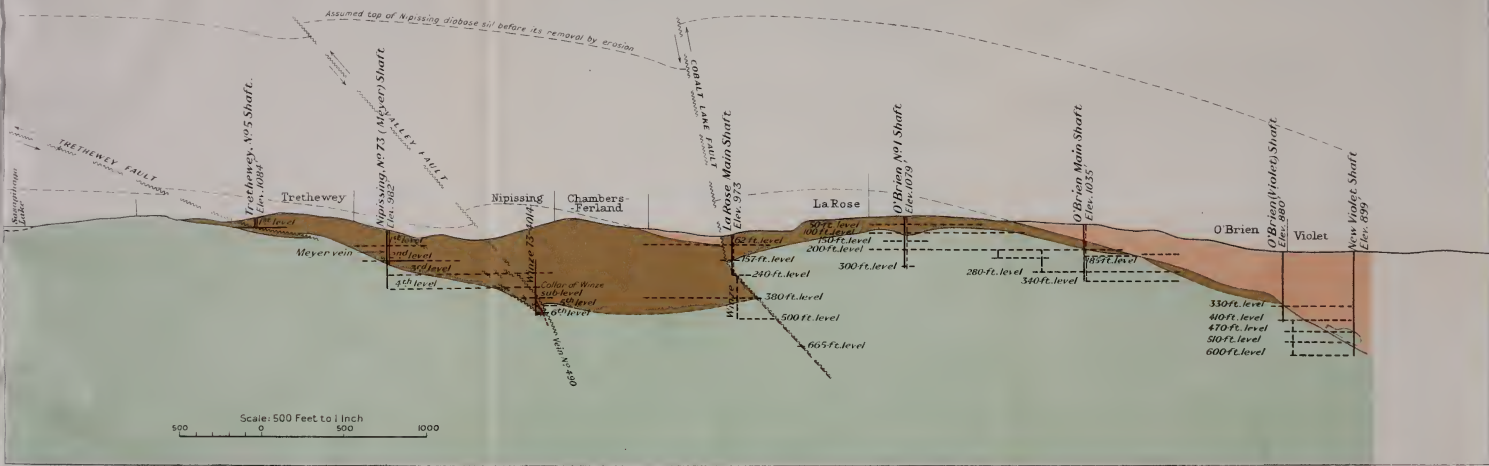
One of the best examples of the way this contact controls the occurrence of the ore is that of the Meyer vein in the Nipissing and Trethewey mines. The Meyer vein extends westward into the Trethewey, and the total length of the ore-shoot on the Trethewey and Nipissing is about 1,600 feet. The shoot, which is all in the Cobalt series, only rises an average height of about 110 feet above the Keewatin (Fig. 5).

The figure shows how the ore-shoot pitches down along the dip of the contact between the Cobalt series and the Keewatin series. The part of the vein above the ore-shoot consists of barren calcite. It may be added that the late Mr. R. B. Watson, the general manager of the Nipissing mine, first explained to the writer how the Meyer ore-shoot followed down along the Keewatin contact.

¹Ont. Dept. Mines, Vol. XXX, pt. III, p. 3.

West

East



VERTICAL SECTION THROUGH NORTH PART OF COBALT, DISTRICT OF TIMISKAMING, ONTARIO.

To accompany Ontario Department of Mines Report, Volume XXXI, Part 2, 1926, by Cyril W. Knight on The Cobalt Silver Area.

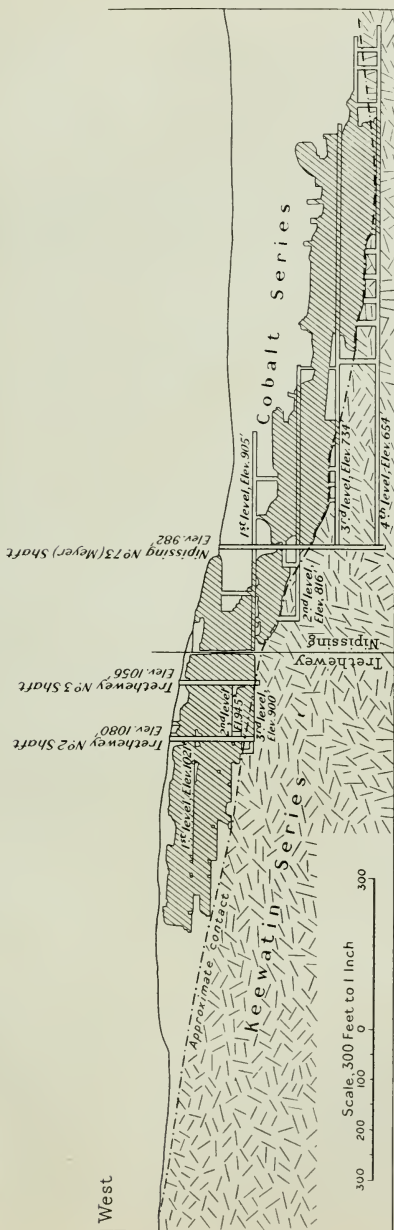


Fig. 5—Stope section on the Meyer vein of the Nipissing and the “main” vein on the Trethewey. The ore-shoot has a length of about 1,600 feet. The ore occurs almost entirely in the Cobalt series. On the Nipissing, the ore-shoot only rises above the Keewatin an average height of about 110 feet; above the stope the vein is a barren calcite vein about three-quarters of an inch wide. Stope sections furnished by the Nipissing and Coniagas.

Another example of the way the contact controls the formation of the silver ore-shoots is the vein-system at the northeast corner of the City of Cobalt mine owned by the Mining Corporation of Canada. The chief veins of this system are known as No. 24 and No. 32. This system of veins, which has a length of some 600 feet, also occurs in the Cobalt series. The ore-shoots in the veins only rise above the Keewatin contact from 100 to 175 feet, above which the veins consist of barren calcite. Indeed, they do not appear to reach the surface, except as narrow joint cracks containing calcite, fractions of an inch wide. The Cobalt series in this area has a thickness of about 400 feet.

Vein No. 490, on the east side of the Nipissing north of Cobalt lake, is another good instance of the way the ore-shoots follow the Keewatin contact. The shoot in this vein is about six or seven hundred feet long, but it does not rise more than about 150 feet above the contact.

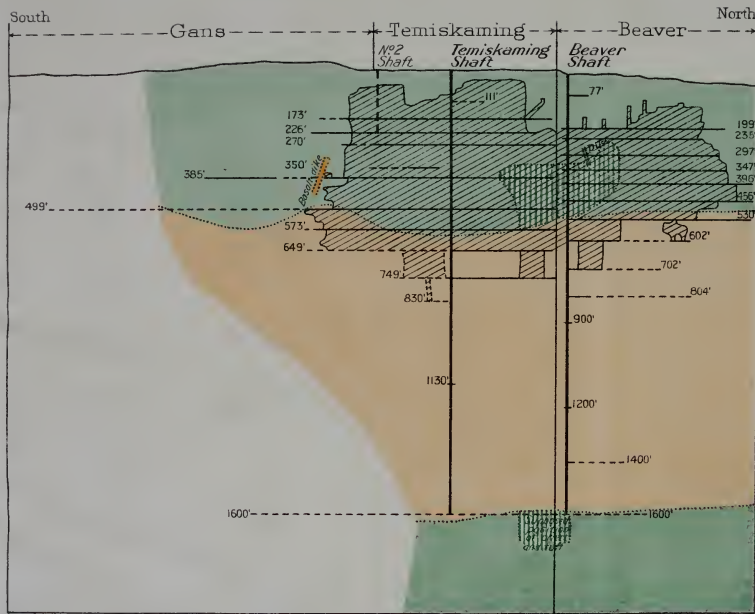
So far as the writer can ascertain the first one to publish the fact that the ore-shoots follow the Keewatin contact was Mr. R. B. Watson, in 1912, in the fifth annual report of La Rose Consolidated Mines Company. Mr. Watson remarks: "The experience in the district has been, that while the conglomerate is the most favourable formation for ore, the ore-bodies usually lie in the vicinity of the Keewatin contact."

The practical importance of a knowledge of this structure need hardly be mentioned here. It must now be clear to anyone that the most promising place to prospect in the area surrounding Cobalt is near the base of the Cobalt series.

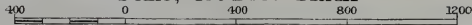
The second contact controlling the formation of ore-shoots is the top of the Nipissing diabase sill, sometimes referred to as the "upper contact." All of the ore so far discovered in South Lorrain occurs along the top of the sill, mostly within two or three hundred feet above or below the contact. In Cobalt itself, practically all of the ore at the Beaver and Temiskaming has been derived from the top of the sill, mostly within 200 feet above or below the contact. The structure of the Nipissing diabase sill and the relation of the veins to the sill at the Beaver and Temiskaming are shown in the coloured cross-sections facing pages 10 and 32.

The third contact controlling the deposition of the ore-shoots is the bottom of the Nipissing diabase sill, sometimes referred to as the "lower contact." All of the ore at the O'Brien and Violet mines has been derived from this contact. The structure at the O'Brien and Violet is illustrated in the coloured cross-section facing page 8. In one instance, that of No. 3 vein at the Kerr Lake mine, the ore-shoot rose to the middle of the sill; it may even have extended to the top of the sill, but erosion has carried away the upper half of the sill at this point. This is the only instance the writer knows in Cobalt in which an ore-shoot extended into the centre of the diabase sill. In Gowganda, however, A. G. Burrows has found that the silver veins at No. 1 shaft of the Castle, R.S.C. 101, are apparently near the centre of the sill.

Another factor governing the control of ore-shoots is the occurrence of faults older than the veins. These faults appear to have acted, in places, as dams or barriers in confining the occurrence of ore-shoots to certain areas. One of the best examples is the Beaver fault, which occurs at the north end of the Beaver-Temiskaming vein-system. No pay ore has been found north of this fault, although some rich ore occurred in the fault itself. Another fault which appears to have governed the deposition of ore-shoots, is that known as No. 64 at the north end of the town of Cobalt (Fig. 8). Only a few hundred thousand ounces of silver have, as yet, been found north of this fault. Nevertheless the discovery of some high-grade ore in the fall of 1923 at the Genesee



Scale, 400 Feet = 1 Inch

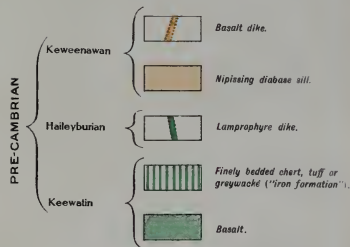


Sheet 31a-5

VERTICAL SECTION PARALLEL TO VEINS NUMBERS 1, 2 AND 3 ON TEMISKAMING MINE AND TO VEIN NUMBER 5 ON BEAVER MINE.

THE AVERAGE STRIKE OF THE VEINS IS
NORTH 16° EAST ASTRONOMIC.

Explanation of Colours

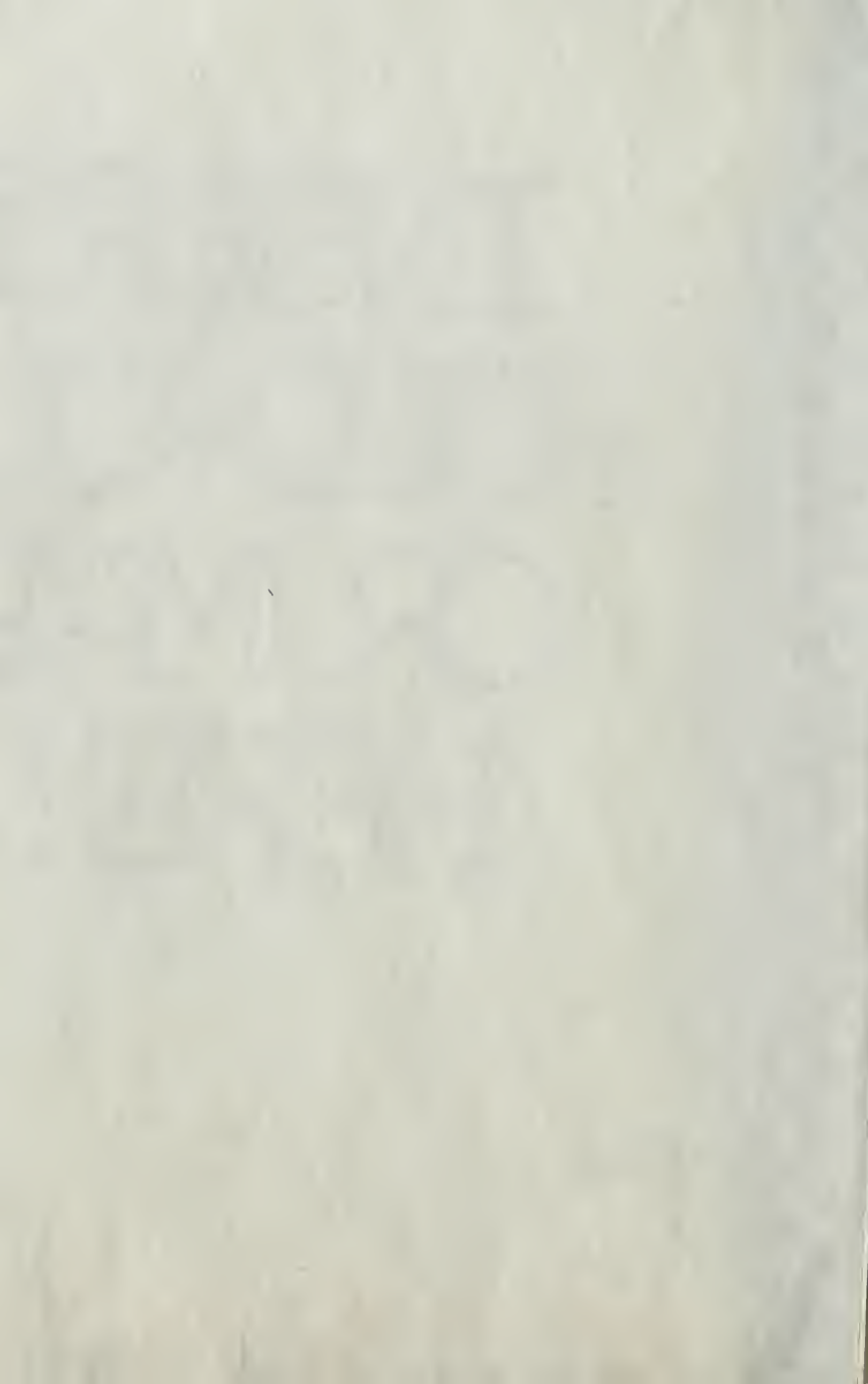


Notes

The collar of Beaver shaft is about eight feet below collar of Temiskaming shaft.

Hatched areas indicate stopes.

The 1600-ft. level of Beaver and Temiskaming was not accessible during the time of examination in the year 1920.



mine, which lies about half a mile north of the fault, lends hope for the discovery of silver ore-shoots under the drift-covered area in and near Genesee.

It should be noted here that the best ore does not necessarily occur along the actual contacts, whether the diabase contacts or the Keewatin-Cobalt series contacts. In some veins there is no pay ore at the actual contact, the ore being from 50 to 100 feet, or more, above or below the contact.

It is a fact that no pay ore, in any important quantity, has yet been found where the Keewatin is absent. Contacts, for example, between the quartzite and Nipissing diabase have not proved productive zones for the deposition of silver.

The occurrence of silver ore under lakes at Cobalt is of interest. Many million ounces have been mined from veins below Kerr, Cart, and Cobalt lakes. It may be that one of the main reasons for the occurrence of ore under these lakes is that the lakes represent lines of weakness or disturbance. Exploration of the rocks below Lake Timiskaming has been, to the end of 1923, neglected. To digress, for a moment, from the Cobalt silver area, it may be noted that in the case of gold, the rocks near or below certain lakes have also been productive of great wealth in Ontario. Pearl lake in Porcupine, and Kirkland lake in the Kirkland lake area have yielded much gold. The Argonaut ore-body is also below a lake—York lake. The only iron mine in Canada of any consequence, the Helen mine, is also below a lake.

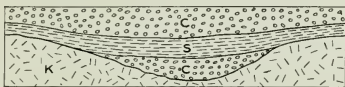


Fig. 6—Ideal sketch showing conglomerate of Cobalt series filling an erosion valley in Keewatin; a bed of slate-like greywacké rests on the conglomerate above the middle of the trough, but directly on the Keewatin on the upper side of the trough. The structure shows that the trough in the Keewatin is largely caused by erosion, not by folding. Structures similar to this occur below or near the beds of Cobalt and Cart lakes.

K—Keewatin series.

C—Conglomerate of Cobalt series.

S—Slate-like greywacké of Cobalt series.

Veins in Cobalt Series Above Depressions in Keewatin

The occurrence of certain vein-systems in the Cobalt series, above or near depressions or troughs in the Keewatin, is an interesting feature of the ore deposits in the Cobalt silver area proper. The most noteworthy of such occurrences was pointed out to the writer by Mr. Warren Emens, geologist of the Mining Corporation of Canada. This occurrence was found by mining operations to exist in an area included in the Buffalo, Townsite, City, and Cobalt lake properties. If the reader will examine, for a moment, the plan No. 31a-12, of these properties, he may observe that this trough is developed on the third, fourth, fifth, and sixth levels. The trough, which strikes southeastward, is shown by the contour of the contact between the Keewatin and the Cobalt series. Many important veins occur above this trough.

Another instance of the occurrence of important veins above a trough in the Keewatin was noted in the Crown Reserve and Kerr Lake mines. The well-known Carson, the Big Chamber, and other veins occur above this trough.

The Meyer vein-system on the Nipissing also appears to occur above a slight trough in the Keewatin. This trough is not as marked or as deep as those referred to above. Indeed, the trough on the Nipissing is only apparent on the third and fourth levels, shown by the contour of the contact between the Keewatin and Cobalt series.

These troughs appear to the writer to have been formed by erosion in the old Keewatin surface (Fig. 6). Possibly a little folding, after the Cobalt series was laid down, may have accentuated the troughs.

Faults

In recent years it has been found that silver ore occurs in many of the prominent faults of Cobalt and South Lorrain. It has been demonstrated, also, that faults have acted as dams or barriers in confining the deposition of silver to certain areas. These two facts, combined with the constant encountering of faults in the mine workings, have led to a close study of faults.

Miller has shown that the region in and around the Cobalt silver area has been subjected to great faulting disturbances, chiefly in a northeast-southwest and a northwest-southeast direction. These faults, which follow the great water courses, divide the rock formations into immense blocks.

We are concerned in this report only with a discussion of the faults around the town of Cobalt, and with the faults in South Lorrain. Something will also be said regarding the Lake Timiskaming fault.

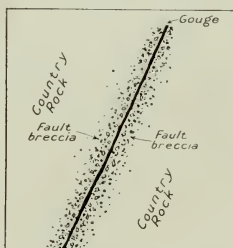


Fig. 7—Drawing illustrating character of faults in the Cobalt area. The heavy black line in the centre represents the gouge, which consists of soft clayey material and fine particles of crushed rock; it is usually less than an inch in width. In places there are two or more gouge planes, about parallel, and a few inches to a foot or two apart. The fault breccia, represented by dots and irregular lines, consists of fine and coarse fragments of the country rock, together with a little clayey material. The fault breccia varies in width from an inch or two, in minor faults, to as much as 15 or 20 feet in the case of a major fault like the Cobalt lake fault.

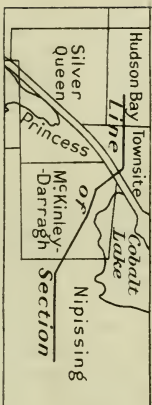
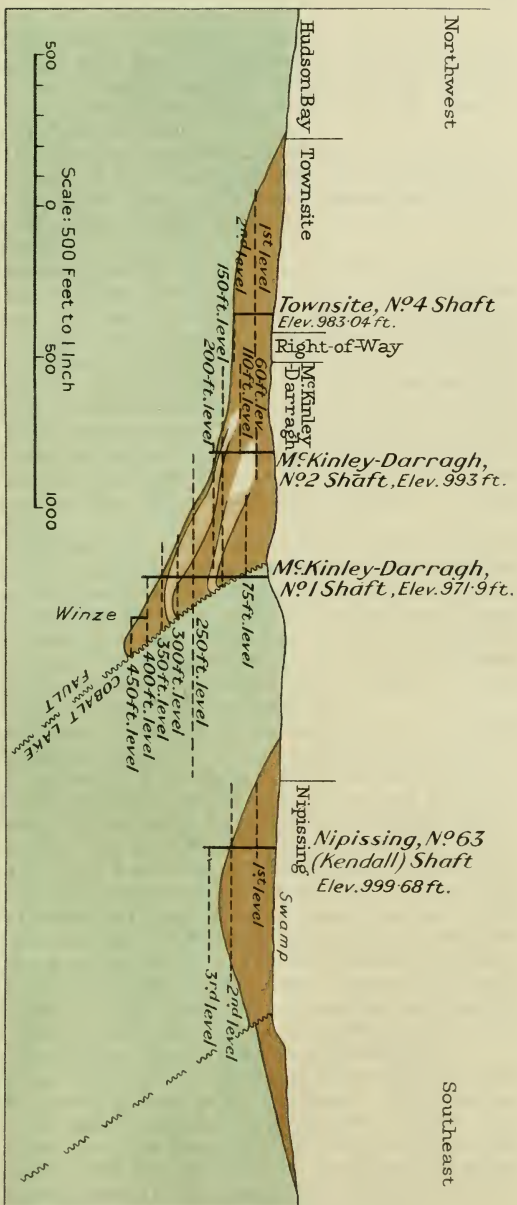
In describing faults throughout this report, the terms "gouge" and "fault breccia" have been used. Following Lindgren,¹ gouge refers to the fine-grained impervious clay, usually a mixture of minerals. Fault breccia refers to the breccia of crushed wall-rock which occurs in the faults. There is usually some clay in the matrix of the fault breccia (Fig. 7).

In certain of the faults at Cobalt the gouge and the fault breccia are sharply distinguished one from the other. That is to say, the gouge may occupy a distinct fracture with smooth walls, the fault breccia being on each side of the gouge. In other faults, the gouge and fault breccia are scarcely distinguishable, the gouge then forming a matrix for the fault breccia.

The main faults in the vicinity of Cobalt and Cross lakes are shown in Fig. 8. They are mostly reverse types, but some are normal. The greatest is probably the Cobalt lake fault, although little is as yet known about the Cross lake fault.

The Cobalt lake fault is a reverse one with a displacement of about 550

¹Lindgren, Waldemar, *Mineral Deposits*, 2nd ed., p. 124.



VERTICAL SECTION THROUGH TOWNSITE, MCKINLEY-DARRAGH AND NIPISSING MINES, COBALT, ONTARIO, SHOWING COBALT LAKE FAULT.

feet at the McKinley-Darragh mine. Proceeding northeastward, however, the displacement becomes less, until at La Rose the displacement is approximately 275 feet. The fault dips 50° to 70° to the southeast. It may be that many of the other faults and fractures in the vicinity of Cobalt lake are the result of stresses connected with the Cobalt lake fault.

Another important fault, though one of less displacement, is that known as the "valley" fault. It is west of the Cobalt lake fault and is shown on the plan (Fig. 8), at the north end of the camp. It is also a reverse fault with a displacement of 75 feet at the point where it could best be studied. It dips 45° to 65° to the southeastward.

West of the Cobalt lake fault and the "valley" fault there occurs a much more gently dipping fault known as the "contact" fault. It is so named because it follows, in a general way, the contact between the Keewatin and Cobalt series, Fig. 20. For the most part it occurs in the Cobalt series a few feet above the Keewatin series, though in places it is found in the Keewatin. Rarely does it occur precisely at the contact. On the Buffalo and Townsite where the fault spans a trough in the Keewatin, the fault is some distance above the Keewatin (Fig. 17). Judging from its occurrence on the Trethewey, the "contact" fault is a reverse one. The displacement is probably less than the "valley" fault. The "contact" fault has been met with again and again in the mine workings of the Mining Corporation properties, the Coniagas, and the Trethewey. Its age relation to the veins is puzzling.

It is likely that the Cobalt lake fault, the "valley" fault and the "contact" fault have all been formed as the result of a compressive force acting from the northwest towards the southeast, and from the southeast towards the northwest. Most of the strain was relieved along the Cobalt lake fault; a lesser amount was relieved along the "valley" fault, and probably a still less amount along the "contact" fault. The three faults are roughly parallel and strike northeastward. These faults are shown in the coloured cross-section facing page 8; in this cross-section the "contact" fault is named the Trethewey fault.

Another group of faults, west of the Cobalt lake fault, may be described together. The faults constituting this group almost parallel one another and strike a little south of east, or about at right angles to the Cobalt lake, "valley," and "contact" faults. The faults of this second group are named, beginning with the southerly one: fault X, galena fault, No. 6 fault, an unnamed fault in the deep bay of Sasaginaga lake, and fault No. 64. Two of these, No. 64 and fault X, have proved to be normal faults with a displacement of less than 25 feet; there may have been some horizontal movement. All of them have vertical or steeply inclined southward dips. Three of these faults have silver ore in them particularly fault No. 64 on the Nipissing, which has been one of the important producers of this company (Fig. 4). This fault appears to form a boundary line at the north end of the camp beyond which a comparatively small quantity of silver has been found. High-grade silver ore, however, was found at the Genesee in the fall of 1923, and also occurs at the Green-Meehan, two miles northeast of the fault, and at the Casey mine 13 miles north of the fault.

Little is known about the Cross lake fault. It occurs in a pronounced valley formed by Cross lake and a string of lakes to the southeast. The writer has never seen the fault in any mine workings. It is reported to have been encountered in a crosscut from one of the workings at the northwest end of the lake. Much water was said to have been encountered. Fault No. 64 strikes towards the Cross lake fault and appears to be a branch of this fault; this remains to be proven by actual mine workings.

what has been called fault No. 64 west of Cobalt lake fault, is really the same fracture that has been called fault No. 64 east of the Cobalt lake fault.

It has been erroneously remarked that the silver deposits of South Lorrain differ from those of Cobalt in one important respect, namely, that the South Lorrain deposits occur in faults, while the ore bodies in Cobalt occur in mere fractures. As a matter of fact, at Cobalt some very important ore bodies occur in faults which have greater displacement than those of South Lorrain. Important ore bodies have, for example, been found in the Cobalt lake fault. Much ore has also been mined from fault No. 64 on the Nipissing. On the whole, however, most of the ore from Cobalt has come from joint planes showing little or no movement.

Coming now to South Lorrain, little need be added to the description of the faults given on page 194 of the chapter on South Lorrain. Economically the most important one is Wood's fault, a reverse one with a displacement of approximately 30 feet. Most of the ore mined during the last two years in South Lorrain has come from this fault or from branches thereof.

Of all the faults briefly referred to above there are none which appear to compare in magnitude with the Lake Timiskaming fault.

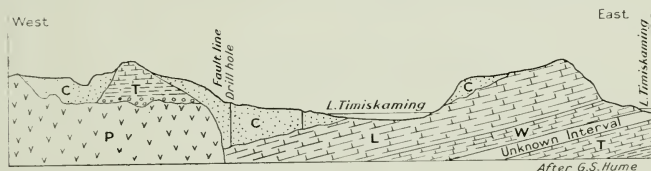


Fig. 9—Vertical section, east and west through New Liskeard; horizontal scale 2 miles to an inch, vertical scale 800 feet to an inch. The Lake Timiskaming fault is shown as "fault line." The rocks on the east side of the fault have been faulted down 800 to 1,000 feet.

C—Post Glacial clay.
L—Lockport formation } Silurian.
W—Walsi formation

T—Haileyburian—Ordovician.
P—Pre-Cambrian.

Lake Timiskaming Fault.—Willet G. Miller was the first geologist to detect the presence of the Lake Timiskaming fault.¹ No mining operations have as yet been carried on in this fault, but its presence is inferred from the fact that Lake Timiskaming follows a narrow, deep depression for its entire length. The most important evidence, however, occurs at the north end of the lake, where the fault cuts across Paleozoic limestones and shales, and the outcrop of the fault has been observed in at least one place. These Paleozoic sediments have been carried down on the east side of the fault 800 to 1,000 feet, according to G. S. Hume (Fig. 9).

The best description of the fault has been given by G. S. Hume,² and owing to its importance as a major fault of the region, a part of Hume's description is given below. The average reader may not have access to the technical journal in which Mr. Hume's paper was published.

A study of the Paleozoic rocks has revealed the presence of a fault which is responsible for the straight western shore of Lake Timiskaming, and a fault-line scarp extending about eighteen miles northwest from the head of the lake. The thickness of the various [Paleozoic] formations included along the fault shows the displacement to be from 800 to 1,000 feet, with the downthrow side to the east. The rocks on the eastern side of the fault are Silurian, with a westward dip,

¹Ont. Bur. Mines, Vol. XIX, pt. II, pp. 119-120.

²Am. Jour. Sci., 4th. ser., 1920, Vol. 50, pp. 293-309.

and near the fault at New Liskeard station a well boring has shown that they are covered with post-glacial deposits over 240 feet thick. At an elevation of over 250 feet higher, on the west side of the fault, Ordovician occurs in flat-lying beds, while on the fault-line scarp itself, Silurian strata outcrop at various places, with beds tilted over 50 degrees to the east. North of the lake, at a higher elevation, pre-Cambrian rocks outcrop to the west of the fault-line, while Silurian occurs to the east, so that the faulting relationships are quite evident. The scarp decreases in elevation to the north, due to the irregularities of the surface having been completely obliterated by the later deposits of post-glacial clay.

Regarding the age of the Lake Timiskaming fault, Hume remarks:—

Since the Silurian rocks have been broken by the faulting, and glacial and post-glacial material are undisturbed, it is obvious that the faulting is post-Silurian and pre-glacial. The presence of a fault-line scarp, now over 150 feet high, which was over 400 feet high before the depression at its base was partly filled with post-glacial clay, is in favour of a date for faulting much nearer the Pleistocene than the Silurian. The fault-scarp is relatively slightly dissected by stream action, so that it is believed it could not have been earlier than the Cenozoic, and the probability is that it is late Tertiary, perhaps connected with the widespread crustal instability and accompanying earth movements which took place in Pliocene time.

It may be added that there are faults in the Cobalt silver area which are not only pre-Cambrian in age, but which are earlier than the Cobalt series. In a fault with such a great displacement as that of the Lake Timiskaming fault it is possible that movement began in pre-Cambrian times, and continued at intervals during Paleozoic or later eras.

Relation of Faults to Veins

Faulting in the pre-Cambrian rocks, as mining operations have now proved, is widespread and complex. The great antiquity of the formations, and the profound disturbances to which, at various times, they have been subjected, show that faulting was not confined to any one period in this great era, but that it must, indeed, have taken place from its most remote times down to its most recent.

To its most recent period, the Keweenawan, belongs the formation of the silver veins.

A little reflection will, therefore, show that when the veins were formed, most of the faults and fractures had already been developed. So that when the silver-bearing solutions began to circulate through the crust of the earth, the solutions found many possible channels through which they could permeate.

Some of these channels offered an easy path of circulation; others were more or less impermeable. Solutions moving through easy paths of circulation would meet with impermeable faults which would stop or impede circulation at certain points and thus confine the formation of ore-shoots within restricted areas.

Curiously enough, these silver-bearing solutions did not choose, as a general rule, the great faults in which to deposit their precious burden. The solutions chose, for the most part, the joint planes and minor fractures. One may wonder why such is the case; why, for instance, more ore was not deposited in such a great fracture as the Cobalt lake fault which has a displacement of more than 500 feet at the McKinley-Darragh mine.

The explanation appears to be that the minor fractures offered easier channels along which the solutions could permeate. Possibly the soft, clayey material in the faults made it difficult for circulation to take place.

While it is true that most of the ore is confined to joint planes and minor fractures, very productive ore-shoots have been found, as already pointed out, in such important faults as Wood's fault in South Lorrain and fault No. 64 on the Nipissing.

Although the above general principles regarding the relations between faults and veins appear simple enough, the practical working out of these relations presents one of the difficult problems in the geology of Cobalt and South Lorrain. Much unpublished discussion regarding the subject has taken place.

The writer believes that most of the important faults are older than the veins. In some cases, however, movement has taken place after the deposition of the ore.

The age relation of some of the faults to the veins is clear. If we consider, for example, three of the faults, namely, the Cobalt lake fault, fault No. 64 on the Nipissing, and fault X on the Townsite, it will be found that vein material in these faults is younger than the faults. The proof that the vein material is younger is found in the fact that high-grade ore occurs in these faults. That is to say, the ore abuts against the gouge of the faults. And as the movement in the fault took place along the gouge, it is evident that a vein cannot be said to be more actually in a fault than when it rests against the gouge.

A different variety of evidence may be given to show that some of the silver veins are younger than faults. This evidence is found at vein No. 490 at the east side of the Nipissing property north of Cobalt lake. The vein cuts through a fault, known as the "valley" fault, which has a reverse displacement of about 75 feet. The vein is not displaced by this fault and must consequently be younger than the fault (Fig. 15).

Again on the City of Cobalt property, vein No. 32 passes through a fault known as the "west" fault and the vein shows little or no displacement.

The "galena" fault on the Buffalo has, in places, a vein of high-grade ore in it, and this vein is therefore younger than the fault.

The "main" vein of La Rose property extends vertically downward into the Cobalt lake fault and is evidently a branch fracture of that fault.

In South Lorrain, Wood's vein and other important veins occur in faults.

It may be remarked here that there appears to have been some later movement in the Cobalt lake fault after the ore was deposited in it. This later movement is shown by the fact that a smaltite vein in the fault at the Princess mine is crushed in places into roundish balls, and these roundish balls are much slickensided. However, this crushing of veins in faults is rare. In the case of the Cobalt lake fault, the extent of the later movement is not known, but judging from the general absence of marked crushing or brecciation of the vein it is likely that the later movement is not of importance.

When we consider, however, the Lake Timiskaming fault, the amount of this later movement was great—probably 800 to 1,000 feet. This later movement took place in Paleozoic times.

Character of Vein-Filling in Faults

It has been shown that most of the faults in Cobalt and South Lorrain are older than the productive silver-bearing veins.

The character of the vein-filling in these faults is sometimes quite different from that in the veins which occupy joint planes. The minerals which are found in small quantities in the faults are: galena, zinc blende, copper pyrites, iron pyrites, marcasite, and quartz, together with pink and white calcite.

It would appear that this kind of vein-filling, namely, galena, zinc blende, iron pyrites, and so forth, belongs to a period of deposition preceding the deposition of the silver ores and cobalt and nickel arsenides.

The older period is characterized by the deposition of sulphides, the younger period by the deposition of arsenides and native silver.

Influence of "Iron Formation" and Lamprophyre Dikes in Formation of Vein Fractures

In a number of cases it has been found that veins in the Cobalt series when traced downwards into the underlying Keewatin pass into steeply dipping beds of slate and chert which have been called "iron formation." When these veins are followed into this formation it has been found in certain cases that they conform approximately in strike and dip with the "iron formation." From this evidence it would appear that the production of some of the joints or fissures in the overlying Cobalt series was guided by the structure of the Keewatin "iron formation" below the Cobalt series.

Miller has already pointed out that certain veins in the Keewatin follow the path of lamprophyre dikes.¹

Ore Reserves and Sampling

As this report was made for the purpose of working out the underground structure of the rocks, no attempt was made to estimate the ore reserves now remaining in the mines. This would have been a task quite beyond the scope of the report. Very little sampling was done by us during our examination. The annual reports of some of the mining companies generally give an estimate of the ore reserves at the respective properties.

Since the discovery of silver at Cobalt in 1903, shipments from the camp and outlying silver areas have been as follows:—

TOTAL SHIPMENTS OF SILVER FROM ENTIRE COBALT AREA, 1904-1923

Year	Average price, cents per ounce (New York)	Silver shipments in Troy ounces, 1904-1923					Montreal River and Maple Mountain
		Total ounces	Cobalt	Casey township ³	South Lorrain ⁴	Gowganda ⁴	
1904	57.221	206,875	206,875	.....	.....	.....	.....
1905	60.352	2,451,356	2,451,356	.....	.....	.....	.....
1906	66.791	5,401,766	5,401,766	.....	.....	.....	.....
1907	65.237	10,023,311	10,023,311	.....	.....	.....	.....
1908	52.864	19,437,875	19,424,251	500	13,124	.....	.....
1909	51.502	25,897,825	25,658,683	26,185	194,955	.....	18,002
1910	53.486	30,645,181	29,849,981	92,544	221,133	471,688	9,835
1911	53.340	31,507,791	29,989,893	114,789	933,912	468,687	510
1912	60.835	30,243,859	28,605,940	253,824	834,119	549,976	.....
1913	57.791	29,681,975	28,105,505	825,108	248,992	502,370	.....
1914	54.811	25,162,841	24,155,699	499,643	108,199	399,300	.....
1915	49.684	24,746,534	24,280,366	223,939	.....	242,229	.....
1916	65.661	19,915,090	19,008,517	445,900	77,280	383,393	.....
1917	81.417	19,401,893	18,327,258	.....	10,000	1,064,635	.....
1918	96.772	17,661,694	16,807,407	143,901	72,188	638,198	.....
1919	111.122	11,214,317	10,314,689	171,278	4,586	723,764	.....
1920	100.900	10,845,436	10,402,249	.....	8,253	433,352	1,582
1921	62.654	8,261,931	7,673,535	1,101	328,886	258,292	117
1922	67.521	10,695,133	9,239,147	1,028	1,284,307	170,651	.....
Total. . .		333,402,683	319,926,428	2,799,740	4,339,934	6,306,535	30,046
1923 ²	64.873	10,493,097	7,375,469	.....	2,955,646	160,761	1,221

¹Ont. Bur. Mines, Vol. XIX, pt. II, p. 71.

²Preliminary figures.

³The entire production from Casey township was obtained by the Casey-Cobalt Silver Mining Company. In the year 1919, the Casey-Kismet Mining Company (northeast ¼, north ½, lot 5, concession VI, Harris township) shipped 28,432 ounces, and the Harris Consolidated Mines, Limited (southeast ¼, south ½, lot 6, concession I, Casey township) shipped 47,570 ounces. Both of these were operated by the Casey-Cobalt Silver Mining Company, and these shipments were included by the Casey-Cobalt Silver Mining Company for the year 1919.

⁴Details of shipments from South Lorrain and Gowganda are given on pages 192 and 28, respectively.

TABLE SHOWING PRODUCTION OF SILVER MINES, 1904 to 1922

Year	No. of pro- ducing mines	Shipments and silver contents								
		Ore			Concentrates and re- sidues			Bullion	Total	
		Tons	Ounces	Av. per ton, oz.	Tons	Ounces	Av. per ton, oz.	Ounces	Ounces	Value
1904	4	158	206,875	1,309					\$	
1905	16	2,144	2,451,356	1,143					206,875	111,887
1906	17	5,335	5,401,766	1,013					2,451,356	1,360,503
1907	28	14,788	10,023,311	677					5,401,766	3,667,551
1908	30	24,487	18,022,480	736	1,137	1,415,395	1,244		10,023,311	6,155,391
1909	31	27,729	22,436,355	809	2,948	3,461,470	1,174		19,437,875	9,133,378
1910	41	27,437	22,581,714	821	6,845	7,082,834	1,030	980,633	25,897,825	12,461,576
1911	34	17,278	20,318,626	1,176	9,375	8,056,189	858	3,132,976	30,645,181	15,478,047
1912	30	10,719	15,395,504	1,436	11,214	9,768,228	871	5,080,127	31,507,791	15,953,847
1913	35	9,861	13,668,079	1,386	11,016	8,489,321	770	7,524,575	30,243,859	17,408,935
1914	32	4,302	6,504,753	1,511	12,152	8,915,958	733	9,742,130	29,681,975	16,553,981
1915	24	2,865	6,758,286	2,359	11,996	10,001,548	834	7,986,700	25,162,841	12,765,461
1916	28	2,177	4,672,500	2,146	8,561	7,598,011	887	7,644,579	24,746,534	12,135,816
1917	28	2,288	3,271,353	1,429	13,720	6,445,243	469	8,053,318	19,915,090	12,643,175
1918	38	1,456	1,401,050	962	17,958	5,793,756	323	10,466,888	19,401,893	16,121,013
1919	33	850	806,341	949	15,208	4,024,212	265	6,383,764	17,661,694	17,341,790
1920	35	578	668,081	1,152	9,757	3,777,812	387	6,402,423	11,214,317	12,738,994
1921	28	948	986,597	1,041	3,101	2,962,771	955	4,312,603	10,846,321	10,654,471
1922	22	1,485	1,712,878	1,154	7,897	1,675,055	212	7,323,194	8,261,931	5,564,594
Total.....		156885	157,285,905	1,002	142885	89,477,803	626	85,033,910	10,711,127	7,658,802

The greatest yield of silver in the Cobalt area was achieved in 1911, when 31,507,791 ounces were shipped. There were 34 producing mines, counting as one mine all the properties owned by the same company or firm. The largest shippers were the following:—

TABLE SHOWING SILVER PRODUCTION IN 1911

COMPANY	TROY OUNCES SHIPPED
Nipissing.....	4,627,043
La Rose.....	4,090,156
Crown Reserve.....	3,430,902
Coniagas.....	3,273,465
McKinley-Darragh-Savage.....	2,551,885
Kerr Lake.....	2,238,353
Buffalo.....	1,644,245
O'Brien.....	1,397,546
Temiskam'ng.....	1,162,317
Hudson Bay.....	1,067,667
Wettlaufer-Lorrain.....	925,017
Beaver.....	888,876
Cobalt Townsite.....	834,949
Trethewey.....	716,464
Cobalt Lake.....	626,044
Miller Lake-O'Brien.....	338,000
Right of Way.....	289,718

DIVIDENDS AND BONUSES PAID BY SILVER MINING COMPANIES TO DECEMBER 31st, 1922

Name of company	Date of incorporation	Authorized capital	Capital stock issued	Par value per share	Amount of dividends and bonuses paid to end of 1921	Amount of dividends and bonuses paid during 1922	Total of dividends and bonuses paid to Dec. 31, 1922	Date when last dividend or bonus paid
Aladdin Cobalt Company, Ltd.	Aug. 23, 1912	\$500,000	\$500,000	\$5.00	\$75,000.00	.....	\$75,000.00	Apr. 30, 1917
Beaver Consolidated Mines, Ltd.	Mar. 1, 1907	2,000,000	2,000,000	1.00	710,000.00	.....	710,000.00	May 31, 1920
Buffalo Mines, Ltd. ¹	Apr. 27, 1906	500,000	500,000	.50	2,787,000.00	.....	2,787,000.00	May 28, 1914
Casey Cobalt Silver Mining Co., Ltd.	Dec. 19, 1906	100,000	100,000	1.00	203,249.33	.....	203,249.33	Apr. 22, 1914
Cobalt Central Mines Co., Ltd.	Dec. 13, 1905	5,000,000	5,000,000	1.00	192,845.00	.....	192,845.00	Aug. 25, 1909
Cobalt Comet Mines, Ltd. ²	Apr. 16, 1913	1,000,000	1,000,000	1.00	230,000.00	.....	230,000.00	Apr. 1, 1915
Cobalt Silver Queen, Ltd.	Apr. 1, 1906	1,500,000	1,500,000	1.00	315,000.00	.....	315,000.00	Dec. 31, 1908
Coniagas Mines, Ltd.	Nov. 24, 1906	4,000,000	4,000,000	5.00	10,940,000.00	\$200,000.00	11,140,000.00	Nov. 1, 1922
Crown Reserve Mining Co., Ltd.	Jan. 16, 1907	2,000,000	1,999,957	1.00	6,190,849.00	.....	6,190,849.00	Dec. 28, 1916
Foster Cobalt Mining Co., Ltd.	Feb. 14, 1906	1,000,000	915,588	1.00	45,000.00	.....	45,000.00	Jan. 1, 1907
Hudson Bay Mines, Ltd.	July 16, 1909	3,500,000	3,200,050	5.00	778,909.42	.....	778,909.42	Aug. 31, 1913
Kerr Lake Mining Company, Ltd.	Aug. 9, 1905	40,000	40,000	100.00	9,475,000.00	380,000.00	9,855,000.00	Oct. 13, 1922
La Rose Mines, Ltd.	May 31, 1908	1,500,000	1,500,000	1.00	7,505,409.56	150,000.00	7,655,409.56	Apr. 20, 1922
McKinley-Darragh-Savage Mines of Cobalt, Ltd.	Apr. 27, 1906	2,500,000	2,247,692	1.00	5,955,391.86	.....	5,955,391.86	Oct. 1, 1920
Mining Corporation of Canada, Ltd. ³	Nov. 23, 1916	8,300,250	8,300,250	5.00	5,498,874.97	.....	5,498,874.97	Sept. 15, 1920
City of Cobalt Mining Co., Ltd. ⁴	{ Oct. 5, 1906 Jan. 7, 1909	500,000 1,500,000	1,500,000	1.00	145,000.00	.....	145,000.00	Apr. 15, 1920
Cobalt Lake Mining Co., Ltd. ⁴	Dec. 22, 1906	3,000,000	3,000,000	1.00	465,000.00	.....	465,000.00	May 29, 1914
Cobalt Townsite Mining Co., Ltd. ⁴	May 8, 1906	100,000	45,011	1.00	1,042,259.61	.....	1,042,259.61	Nov. 11, 1914

Nipissing Mining Co., Ltd. ⁵	Dec. 16, 1904	250,000	250,000	100.00	24,293,297.25	1,120,000.00	25,413,297.25	Oct. 20, 1922
Penn-Canadian Mines, Ltd. ⁶	Apr. 24, 1912	1,500,000	1,500,000	1.00	175,461.65		175,461.65	Sept. 10, 1917
Peterson Lake Silver-Cobalt Mining Co., Ltd.	Apr. 11, 1906	3,000,000	3,000,000	1.00	462,350.35		462,350.35	Jan. 2, 1917
Right of Way Mining Co., Ltd.	July 13, 1906	500,000	500,000	1.00	324,643.93		324,643.93	Oct. 1, 1909
Right of Way Mines, Ltd.	Sept. 11, 1909	2,000,000	2,000,000	1.00	252,825.00		252,825.00	Mar. 17, 1917
Seneea-Superior Silver Mines, Ltd.	Sept. 29, 1911	500,000	500,000	1.00	1,579,817.20		1,579,817.20	Dec. 15, 1916
Temiskaming Mining Co., Ltd.	Nov. 5, 1906	2,500,000	2,500,000	1.00	2,159,156.25		2,159,156.25	Jan. 31, 1920
Temiskaming and Hudson Bay Mining Co., Ltd.	July 10, 1903	25,000	25,000	1.00	1,940,250.00		1,940,250.00	Nov. 10, 1914
Trethewey Silver Cobalt Mines, Ltd.	May 30, 1906 June 1, 1911	2,000,000	2,000,000	1.00	1,211,998.50		1,211,998.50	Jan. 2, 1919
Wetlaufer Lorrain Silver Mines, Ltd.	Nov. 30, 1908	1,500,000	1,500,000	1.00	637,465.50		637,465.50	Sept. 22, 1913
Total					\$85,592,054.38	\$1,850,000.00	\$87,442,054.38	

¹ In 1917 the capital stock of the company was reduced from \$1,000,000 to \$750,000, in 1918 from \$750,000 to \$500,000, and on December 21, 1919, from \$500,000 to \$150,000, by returning to shareholders amounts equal to the reduction in capital, leaving 300,000 shares issued of 50 cents each. The mine was sold to the Mining Corporation of Canada, and operated by it in 1920 and subsequently.

² Cash assets amounting to \$50,000 paid on April 27, 1917.

³ Mining Corporation of Canada, Limited, owns and operates the City of Cobalt, Cobalt Lake, and Cobalt Townsite mines.

⁴ Now owned and operated by Mining Corporation of Canada, Limited.

⁵ Includes \$16,288,297.25 paid in dividends by the Nipissing Mines Co. (the holding company) to the end of 1916.

⁶ Paid out of capital \$40,491.15 on Sept. 10, 1917, and an equal amount on April 24, 1918.

GOVERNMENT REVENUE AND SILVER PRODUCTION

The silver mines of the entire Cobalt area have paid in royalties to the Ontario Government the sum of \$2,067,153, to October 31st, 1923.

The following table gives the amounts paid by various companies. These royalties have nothing to do with the taxes. Every company which is making a sufficient profit is subject to taxes. Only companies which bought or leased certain lands under special agreement from the Ontario Government are subject to the payment of royalties.

Royalties to October 31st, 1923, paid to the T. & N. O. Railway Commission, as set forth in their annual reports, amounted to \$1,059,440.31. This is in addition to the figures given in the table below:—

TABLE SHOWING ROYALTIES RECEIVED BY THE ONTARIO GOVERNMENT

MINE	ROYALTY
O'Brien	\$884,322.82
Crown Reserve	812,410.91
Hudson Bay	333,870.05
Chambers-Ferland	26,259.64
Provincial	6,735.14
Hargrave	1,200.00
Wyandoh	1,421.72
Waldman	932.72
Total	\$2,067,153.00

Royalty agreements have terminated, and producing mines now pay a Profit Tax under the provisions of the Mining Tax Act.

The Ontario Government received \$1,532,162.51 as Profit Tax from the silver mines to October 31st, 1923, the end of the fiscal year.

In the matter of the sale of Cobalt lake, Kerr lake, and lots in the Gillies limit, the Government received \$1,640,139.11, distributed as follows:—

Cobalt lake (1907)	\$936,500.00
Kerr lake (1907)	178,500.00
¹ Gillies limit lots (1908-10), including Provincial mine ore sales and property sale (surplus receipts over expenditure)	527,523.64
Total	\$1,642,523.64

¹ The gross revenue was \$836,886.63.

SILVER PRODUCTION FROM THE COBALT AREA PROPER¹—TROY OUNCES SHIPPED

Year	Nipissing	Cobalt Lake	Cobalt Townsite	City of Cobalt	Mining Corporation	Contiagas	Kerr Lake	La Rose ²	Crown Reserve	McKinley-Darragh-Savage
1904	32					130,853	128,805	112,500		7,873
1905	753,154					567,009	425,000	311,847		235,262
1906	2,214,822					1,369,005	676,000	880,100		42,354
1907	2,239,552		60,963	65,950		1,369,995	1,551,324	771,473		611,798
1908	2,893,031	74,934	108,827	503,772		1,416,731	3,112,067	1,759,479	1,698,955	667,970
1909	4,046,869	46,732		432,959		2,621,681	2,877,299	3,185,051	4,034,325	1,324,372
1910	5,596,136	239,728	195,597	305,216		3,273,465	2,238,353	2,769,266	3,248,196	2,606,891
1911	4,678,074	626,044	834,949	214,876		3,703,942	1,895,309	4,090,156	3,430,902	2,551,885
1912	4,719,578	1,123,146	1,505,396	207,951		3,252,566	2,072,407	2,920,344	2,714,765	2,694,560
1913	4,844,169	980,858	2,314,602	100,158				2,592,775	1,776,678	2,228,832
		3,091,442	5,020,334	1,830,752	9,942,528					
			Townsite-City							
			3,079,275							
1914	3,999,863	1,247,677	2,776,589		4,326,952	2,459,007	1,817,087	1,398,404	1,425,320	1,260,046
1915	4,623,958	1,566,206	3,115,638		4,342,795	1,916,616	2,109,355	1,071,694	512,396	1,061,827
1916	3,819,768	994,608			4,110,246	1,816,287	2,527,092	830,707	262,470	1,055,959
			8,971,502							
1917	3,798,802				4,546,065	1,273,853	2,302,466	478,639	309,420	1,013,602
1918	4,116,077			See description of City of Cobalt mine	1,994,061	1,006,104	2,221,811	276,130	301,507	885,530
1919	3,080,070				1,088,064	918,063	802,243	290,227	265,853	760,787
1920	2,814,852				1,815,594	990,176	610,604	492,801	65,232	613,428
1921	3,016,760				911,899	1,301,860	78,391	658,423	1,121	82,189
1922	3,845,012				1,184,652	1,899,571		434,560	16,959	254,308
Total	65,700,579	6,899,933	15,822,588		34,262,856	31,286,744	27,445,583	25,324,576	20,064,099	19,959,473

¹Shipment figures below do not necessarily agree with production figures as published in annual reports of the operating companies.²La Rose, Lawson, Violet, University, Princess; for production of these mines see description under La Rose.³Includes Buffalo.

SILVER PRODUCTION FROM THE COBALT AREA PROPER—TROY OUNCES SHIPPED—Continued

Year	O'Brien	Buffalo	Temiskaming	Trethewey	Hudson Bay ¹	Beaver	Seneca-Superior (Peterson Lake Lease)	Standard (Cobalt-Central-Penn-Canadian)	Drummond (Cobalt-Comet) ²	Right of Way
1904	117,055	82,068	55,320	63,020					26,400	
1905	145,012	210,598	345,602	7,620					287,348	86,349
1906	1,584,920	466,969	127,848	257,370					256,626	216,801
1907	1,765,073	903,126	327,527	1,116,387					718,793	447,585
1908	1,576,411	1,272,649	1,013,874	717,183					74,960	773,162
1909	1,162,303	1,629,327	616,312	727,237					120,573	455,986
1910	1,397,546	1,644,245	1,994,226	846,579					149,282	289,718
1911	1,091,631	1,890,150	1,162,317	716,464					146,625	59,973
1912	1,240,931	1,732,199	1,217,994	620,923					232,348	99,401
1913	1,231,834	912,350	768,939	599,036					384,945	122,227
1914	991,084	957,831	323,022	543,097					507,366	102,274
1915	776,068	267,468	1,486,400	126,010					185,504	122,928
1916	1,064,335	645,915	873,507	190,988					32,128	110,963
1917	1,074,312	870,247	887,122	311,324					20,629	49,723
1918	648,501	577,811	517,763	291,269						5,819
1919	1,179,706		194,270	181,078						18,444
1920	1,366,686		298,627	48,373						
1921	896,195		33,952	30,057						
1922				3,715						
Total	18,342,603	14,082,953	11,681,900	6,844,739	6,611,316	6,174,719	5,527,596	3,752,610	3,707,137	2,961,353

¹Name of company changed from Temiskaming and Hudson Bay in 1909.²In 1913 the Drummond Mines Company produced 136,133 ounces and Cobalt Comet 248,812 ounces.³Included with Mining Corporation of Canada.⁴Included with Coniagas.

SILVER PRODUCTION FROM THE COBALT AREA PROPER—Troy Ounces Shipped—Continued

Year	Cobalt Silver Queen	Chambers- Ferland	Aladdin Cobalt	Dominion Reduction Co. (Dominion Mine)	Foster	Nova Scotia	Peterson Lake	King Edward (National)	Har- grave	Silver Leaf	Silver Cliff	Colonial
1904	.....	Cobalt ore	.....	.....	110,000	.....	.....	Watts—3,160	12,056	.....	.....	.....
1905	.....	.....	.....	.....	64,450	10,785	.....	.....	.....	900	.....	.....
1906	195,807	.....	.....	.....	209,000	112,000	.....	.....	.....	51,121	.....	17,219
1907	182,987	.....	.....	.....	99,500	110,136	.....	.....	.....	343,112	70,267	359
1908	589,693	69,477	.....	.....	.....	157,222	55,081	.....	.....	.....	115,879	.....
1909	145,210	214,755	.....	.....	.....	271,981	120,367	.....	.....	.....	143,921	61,336
1910	2,091	335,853	.....	.....	.....	145,694	249,491	.....	.....	7,371	49,755	192,159
1911	.....	94,030	.....	.....	.....	.....	134,653	.....	.....	.....	.....	91,603
1912	.....	119,203	.....	.....	.....	.....	.....	.....	.....	.....	.....	23,445
1913	.....	69,467	.....	.....	.....	.....	31,253	.....	.....	.....	.....	.....
1914	.....	205,025	.....	.....	7,145	.....	23,639	.....	.....	.....	.....	.....
1915	36,545	.....	.....	.....	.....	.....	.....	.....	.....	84,000	.....	.....
1916	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1917	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1918	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1919	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1920	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1921	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1922	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total	1,225,111	1,107,810	1,067,658	973,361	815,346	807,818	744,343	653,713	506,972	487,956	404,080	388,081

SILVER PRODUCTION FROM THE COBALT AREA PROPER—TROY OUNCES SHIPPED—Continued

Year	Drummond Fraction	Bailey	Provincial	University (La Rose)	Green- Mechan and Red Rock	Cart Lake	Nancy- Helen	Little Nipissing	Mercer	Reliance	Angus, D. H. (Nip. Red Co. Mill clean-up)
1904.....											
1905.....				26,110							
1906.....				149,200							
1907.....				24,245	77,996		20,000				
1908.....			19,041				31,569	4,138			
1909.....			18,410	9,317			37,106	78,970			
1910.....			124,381				3,095				
1911.....			15,686		10,268						
1912.....		48,335			2,560						
1913.....		131,431				99,700					
1914.....	144,631	15,080									
1915.....	104,450			19,482							
1916.....	40,450								81,998		
1917.....	67,112		7,000								13,182
1918.....			11,634	See University Mine		See Seneca- Superior				3,636	22,040
1919.....			20,214		74,066					21,425	10,563
1920.....		8,401			17,025					20,671	
1921.....		67,706	29,466		44,274					675	
1922.....		15,647								659	
Total.....	356,643	286,600	245,832	228,354	223,629	99,700	91,770	83,108	81,998	47,066	45,785

SILVER PRODUCTION FROM THE COBALT AREA PROPER—TROY OUNCES SHIPPED—Continued

Year	Glen Lake	Argentum	Waldman	Cochrane	Wyandoh	Adanac	Silver Bar	Lumsden	York- Ontario	Rochester Cobalt	Ruby	North Cobalt
1904												
1905												
1906												
1907												
1908												
1909		33,055	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1910		561	28,858	.....	26,651	.....	.....	.....	.....	11,696	.....	1,453
1911					2,586	.....	.....	.....	.....	.....	.....	.....
1912												
1913				3,272	.....	.....	21,981	18,129	17,198	.....	.....	.....
1914				29,750	.....	.....	.....	.....	.....	.....	.....	.....
1915												
1916	42,605	.....	.....	.....	.....	.....	.....	.....	.....	1,763	.....	.....
1917						2,620	.....	.....	.....	.....	.....	.....
1918			165	.....	.....	427	.....	.....	.....	.....	.....	.....
1919			4,381	.....	.....	25,010	.....	2,026	.....	.....	.....	.....
1920												
1921								933	.....	.....	8,702	.....
1922												
Total...	42,605	33,616	33,407	33,022	29,237	28,057	21,981	21,088	17,198	13,459	8,702	1,453

SHIPMENTS FROM GOWGANDA MINES, 1910-1922

Mine	Ore and Concentrates, Tonnage Shipped													Total cobalt paid for, lbs.	
	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922		Total tons
Bartlett	*													72.20	20219
Crews-McFarlan	3.79													16.85	10046
Bonsall	27.00								30.20	42.00	13.06			27.00	4678
Boyd Gordon	1.80													1.8	
Burk-Remy	*														
Calcite Lake															
Canadian Gowganda	*														
Castle-Trethewey											45.31	29.88	10.87	86.06	122423
Everett	*														
Kell			13.74	15.87	18.00						0.79			0.79	1621
Mann	347.00	128.0	192.00											47.61	97792
Millerett	31.00	141.5	112.60	166.90	113.90	109.66	170.57	350.00	160.40	189.79	115.09	103.07	75.80	667.00	611822
Miller Lake O'Brien	*														5000
Powerful	54.00						11.00	5.75		1.94	10.44			83.13	5348350
Reeve-Dobie	1.00														88584
Welch														1.00	1000
TOTALS															
Ore and Conc.	465.59	269.5	318.34	182.79	131.90	109.66	181.57	355.75	190.60	233.73	184.69	132.95	86.67	2844.74	
Silver	471688	468687	549976	502370	399300	242229	383393	1064635	638198	723764	433352	258292	170651	6306535	
Cobalt (paid for)	8432							56884	26994	27404	15236	9187	8478		152615

*In addition to the shipments reported to the Department of Mines and shown in the table of production, A. A. Cole's reports for the Temiskaming and Northern Ontario Railway Commission show the following additional shipments:—

1909—Bartlett, 2 tons.

1910—Everett, 8.35 tons; Powerful, 1 ton.

1911—Calcite Lake, 8.5 tons; Canadian Gowganda, 8 tons.

Note:—Shipments of about 6½ tons have been reported in addition from the Hudson Bay properties in Leith township.

The silver contents of the Burk-Remy shipment were never reported to the Department.

Silver Production from Important Localities in the World Compared

A comparison of the silver yield of the entire Cobalt area with the yield of other great silver camps of the world, shows that Cobalt has been the fourth largest producer of silver. The following table has been compiled largely from information obtained from a text-book by Beyschlag, Vogt, and Krusch.

COBALT'S SILVER PRODUCTION COMPARED WITH THAT OF OTHER DISTRICTS¹

LOCALITY	SILVER PRODUCTION (metric tons)	YEARS
Potosi, Bolivia.....	30,000	Since 1545
Guanajuato, Mexico.....	15,000	Since 1558
Zacatecas, Mexico.....	14,000	1548-1832
Cobalt, Canada ²	10,375	1904-1922
Freiberg, Germany.....	5,243	1163-1896
Comstock, Nevada.....	4,820	1859-1889
Pachuca, Mexico.....	3,500	1522-1901

WORLD'S AVERAGE ANNUAL PRODUCTION OF SILVER, 1493-1912³

PERIOD	AVERAGE ANNUAL PRODUCTION (ounces)	PERIOD	AVERAGE ANNUAL PRODUCTION (ounces)
1493-1544 (52 years).....	2,152,070	1821-1860 (40 years).....	21,966,300
1545-1600 (56 years).....	11,111,040	1861-1869 (9 years).....	38,800,000 ⁴
1601-1700 (100 years).....	11,970,730	1870-1887 (18 years).....	74,502,470
1701-1800 (100 years).....	18,336,720	1888-1907 (20 years).....	158,037,350
1801-1820 (20 years).....	23,066,340	1908-1912 (5 years).....	217,499,950

WORLD'S ANNUAL PRODUCTION OF SILVER, 1901-1921⁵

YEAR	FINE OUNCES	YEAR	FINE OUNCES
1901.....	173,011,283	1912.....	226,251,013
1902.....	162,763,483	1913.....	225,410,085
1903.....	167,689,322	1914.....	168,452,942
1904.....	164,195,266	1915.....	184,204,745
1905.....	172,317,688	1916.....	168,843,000
1906.....	165,054,497	1917.....	174,187,800
1907.....	184,206,984	1918.....	197,394,900
1908.....	203,131,404	1919.....	174,517,400
1909.....	210,453,431	1920.....	174,212,686
1910.....	222,879,362	1921.....	171,285,542 ⁶
1911.....	225,372,844	1922.....	213,541,784 ⁷

YEARLY AVERAGE PRICE OF SILVER, 1895-1923, NEW YORK⁷

YEAR	PRICE PER OUNCE cents	YEAR	PRICE PER OUNCE cents
1895.....	65.250	1910.....	53.486
1896.....	67.060	1911.....	53.340
1897.....	59.790	1912.....	60.835
1898.....	58.260	1913.....	59.791
1899.....	59.580	1914.....	54.811
1900.....	61.330	1915.....	49.684
1901.....	58.950	1916.....	65.661
1902.....	52.160	1917.....	81.417
1903.....	53.570	1918.....	96.772
1904.....	57.221	1919.....	111.122
1905.....	60.352	1920.....	100.900
1906.....	66.791	1921.....	62.654
1907.....	65.237	1922.....	67.521
1908.....	52.864	1923.....	64.873
1909.....	51.502		

¹"The Deposits of the Useful Minerals and Rocks," by Beyschlag, Vogt and Krusch. 1916, translated by S. J. Truscott, pp. 202, 529, 675.

²Shipments for 1922 added to those in the text book.

³Report on Silver, published by the Imperial Mineral Resources Bureau, 1923.

⁴The production for several years of this period is only approximately known.

⁵Eng. & Min. Jour.; and Report on Silver, published by Imperial Mineral Resources Bureau, 1923.

⁶Annual Report, 1923, Director of United States Mint.

⁷Eng. Min. Jour.-Press, Jan. 19, 1924, p. 140.

GENERAL GEOLOGY

A brief outline of the general geology will be given in order to make the report intelligible; and below will be found a legend showing the rock formations in northeastern Ontario, including the Cobalt silver area, the Sudbury nickel area, and the Porcupine and Kirkland lake gold areas.

LEGEND

(After Willet G. Miller)

PLEISTOCENE

*Glacial drift, post-glacial clays,
sands, gravels.*

PALEOZOIC

Silurian and Ordovician

*Limestone shales, sandstone,
basal conglomerate.*

GREAT UNCONFORMITY

EOZOIC OR PRE-CAMBRIAN

(Keweenawan)

Granite

INTRUSIVE CONTACT

*Diabase dikes, Nipissing diabase
sill at Cobalt, and norite at
Sudbury.*

INTRUSIVE CONTACT

Animikean

Upper Cobalt Series

Arkose and quartzite.

Lower Cobalt Series

Conglomerate, quartzite, greywacke.

GREAT UNCONFORMITY

(Matachewan)

Diabase dikes, etc.

(Algoman)

Granite, syenite, porphyry, etc.

(Haileyburian)

Lamprophyre, diabase, serpentine, etc.

INTRUSIVE CONTACT

Timiskamian

*Conglomerate, quartzite,
greywacke, slate.*

GREAT UNCONFORMITY

(Laurentian)

*Gneissoid granite, banded gneiss.
Probably also includes much
granite of later age.*

INTRUSIVE CONTACT

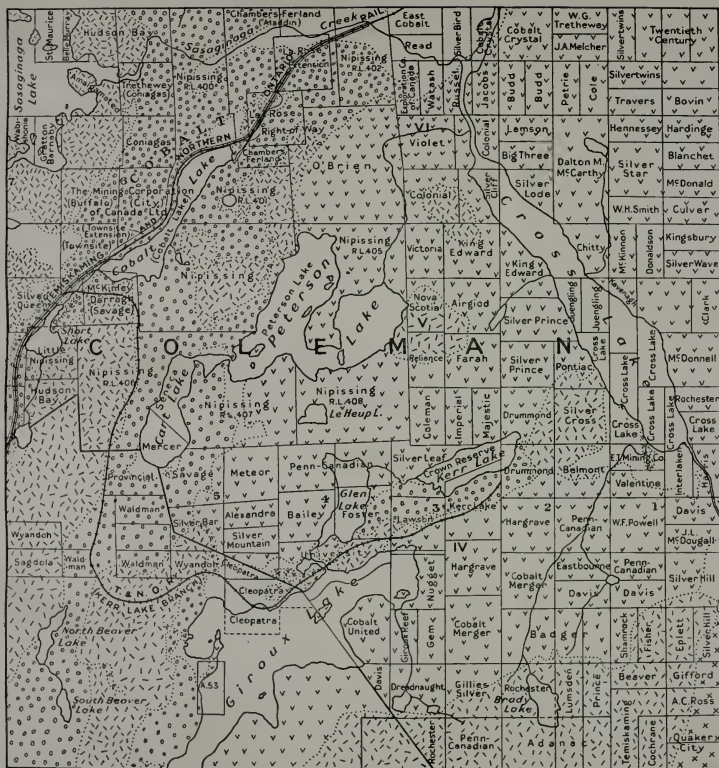
Loganian

Grenville

*Crystalline limestone, etc.
Jaspilite or "iron formation."*

(Keewatin)

*Green schists, amygdaloidal ba-
salt, ellipsoidal basalt,
andesite, acid porphyries, etc.,
essentially lava flows.*



LEGEND

Glacial and Recent

PRE-CAMBRIAN

Nipissing Diabase

IGNEOUS CONTACT

Cobalt Series
Conglomerate, quartzite, etc.

Matachewan
Diabase dikes, etc.
(not shown)

Algoman
Garnet granite.

Haileyburian
Lamprophyre, diabase, etc.
(not shown)

Timiskamian
Conglomerate, etc.
(not shown)

Kewatin
Basic lavas, etc.

North Arrow

Scale $\frac{1}{31,680}$ or 40 chains to 1 inch
Chains 40 20 0 40 80 Chains

General geological map of Cobalt area.

With the exception of a small outlier of fossiliferous rocks of Paleozoic age, the rocks belong entirely to the pre-Cambrian.

A description of the rocks which are more immediately associated with the silver ores will be found sufficient for the requirements of a report such as this.

The oldest series, known as the Keewatin, consists mainly of basaltic lava flows, interbedded with which are beds of "iron formation" consisting of slate, chert, and greywacké, the whole series of basalts and "iron formation" having been tilted up into vertical position.

The Timiskaming series of conglomerate, slate, greywacké, and quartzite was laid down on top of the Keewatin. These two series, the Keewatin and Timiskaming, have been intruded by many lamprophyre dikes of Haileyburian age. The dikes are, for the most part, two or three to fifteen or twenty feet in width.

All of the rocks mentioned in the preceding paragraph were then intruded by a great mass of pink granite of Algoman age.

A prolonged period of weathering and erosion then followed, and the rocks were planed down to a surface probably not much unlike the surface existing in northern Ontario at the present time.

On this ancient basement, rest the rocks of the Cobalt series. This series is of immense importance owing to the fact that most of the silver has been mined from veins in it. The Cobalt series consists of beds of fine and coarse boulder conglomerate, greywacké, slate-like greywacké, and quartzite. It has a thickness of about 600 feet at the north end of Cobalt lake.

The great geological event of most importance to the miner then took place. This consisted of the intrusion of an enormous sill of diabase about 1,000 feet thick. The sill has been named the Nipissing diabase and is of Keweenawan age. Its importance is due to the fact that the silver veins have been deposited from mineral solutions which were given off by it during the time it was cooling and for some time after it had solidified and had been faulted.

Dikes of diabase cut all of the rocks above described and also, apparently, the silver veins.

What is known as the Pleistocene epoch, or most recent time, was not a beneficent one in its relation to the ore deposits of northeastern Ontario. During this epoch a great sheet of ice known as the Labradorean sheet accumulated in Labrador. It spread out in all directions, part of it coming southward and southwestward, and sweeping the rocks clean of their weathered and decomposed surface. In doing so the upper parts of ore-bodies have been carried away and mixed with the glacial debris. Only in a few places, as at the Keeley silver mine in South Lorrain, has any remnant of this pre-glacial weathering been preserved in the Province of Ontario.

Structure of the Rocks

The structure of the rocks is illustrated in the coloured vertical section facing page 8. This section is drawn through the most productive part of the camp, passing as it does through, or in the vicinity of, the Coniagas, Trethewey, Nipissing, La Rose, and O'Brien mines.

The great extent of the underground work in this locality through which the cross-section passes has made it possible to show, with tolerable accuracy, the relation of the rocks, one to another, and to the veins and faults. The writer believes that if the reader will make a close study of this cross-section, he will gain a better idea of the structure of the rocks than could be acquired by perusing several pages of descriptive writing.

The structure of the Nipissing diabase sill, and its relation to the silver veins, is best studied at the Beaver and Temiskaming mines. There the entire sill has been preserved from erosion. This structure is illustrated in the coloured cross-section facing page 32. The reader is referred to this section if he would understand the structure in this part of the camp.

Folding

Some of the rocks in the Cobalt silver area have been greatly disturbed. The lava flows, for example, of the Keewatin series have been severely folded and are now found in vertical or almost vertical attitudes. Although these Keewatin lava flows have been strongly folded they have not been altered to schists such as are commonly found in the Porcupine gold area 107 miles north-west of Cobalt. The vertical attitude of the flows in Cobalt may be seen in the area between Cobalt and Sasaginaga lakes.

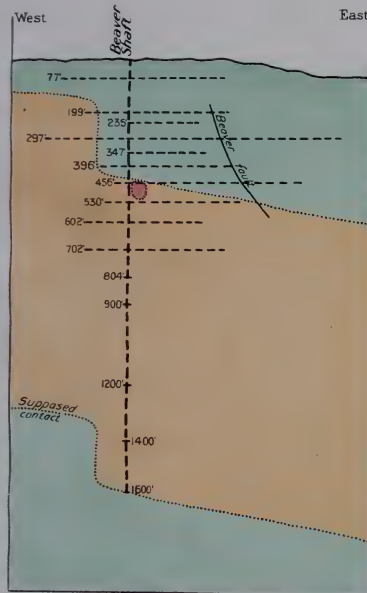
The sediments of the Timiskaming series are also steeply folded. These rocks are exposed along the shores of Lake Timiskaming between Haileybury and New Liskeard. They have been tilted up into vertical or nearly vertical attitudes.

The formations of most importance to the miner belong to the Cobalt series. They are not disturbed as much as the Keewatin or Timiskaming. The Cobalt series in places rests in almost horizontal attitudes. In other places the series dips at gentle to somewhat steep angles. In the area around Diabase mountain the slate-like greywacké of the Cobalt series is almost horizontal as is shown in the coloured cross-section facing page 40. But in the vicinity of the town of Cobalt the sediments of this series have been disturbed by the Cobalt lake and other faults shown in Fig. 8. The bed of Cobalt lake forms a decided syncline with the sediments dipping towards the long axis of the lake at angles from 10 degrees or 20 degrees to as high as 45 degrees or more in the vicinity of the Cobalt lake fault. The fault is shown in the coloured cross-section facing page 12.

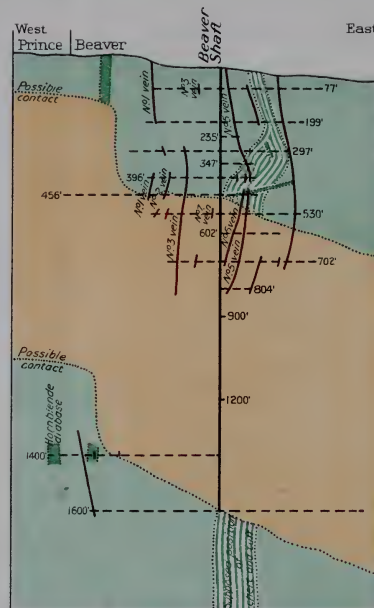
Coming now to an important rock formation, namely, the Nipissing diabase sill, it is certain that some folding, particularly around Cobalt lake, took place in this great sheet of rock, the thickness of which is about 1,000 feet. The sill has been faulted by the Cobalt lake fault—exactly how much is not known; in the coloured cross-section facing page 8, an attempt has been made to estimate the amount of this displacement which was caused by the Cobalt lake fault. While it is thus evident that the sill was folded to a certain extent in the vicinity of the Cobalt lake fault, there are other places in the sill which show apparent, not real, sharp folding, such as in the Kerr lake area. The sill in this area forms a structure known as the Kerr lake dome. This is dealt with in the following paragraphs.

The Kerr Lake Diabase Dome

In the Kerr lake area the Nipissing diabase has the form of an elongated dome, known as the Kerr lake dome. This anticline-like structure is shown in the vertical section facing page 34. A study of the coloured section, which is drawn through the Crown Reserve mine, will convince one that folding did not cause the diabase to acquire its anticline-like structure. It will be noted that the sediments of the Cobalt series below the dome are resting at almost horizontal or gently dipping angles. Had the diabase sill been folded into a sharp anticline, the sediments of the Cobalt series immediately below would not only have been folded into an anticline, but also altered to schists. The same structure was



Vertical Section A-A, through Beaver mine, 350 feet north of main shaft.



Vertical Section B-B, through main shaft of Beaver mine.



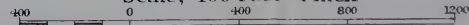
Vertical Section C-C, through Temiskaming mine, 225 feet north of main shaft.

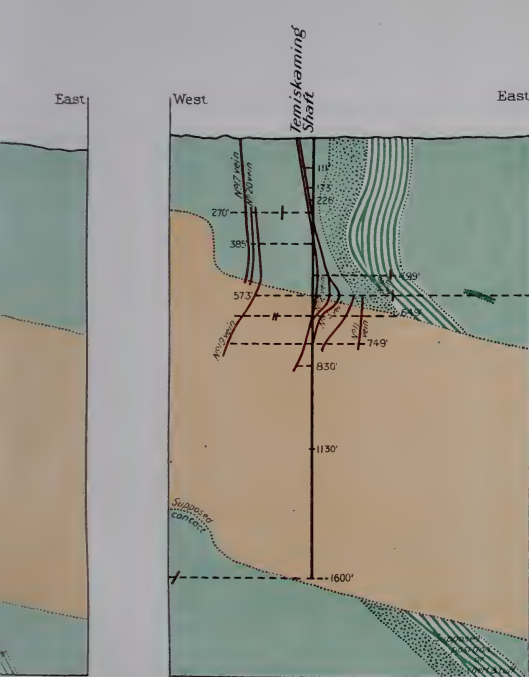
Sheet 31a-4

VERTICAL SECTIONS EAST AND WEST THROUGH BEAVER AND TEMISKAMING MINES
COBALT, DISTRICT OF TIMISKAMING, ONTARIO

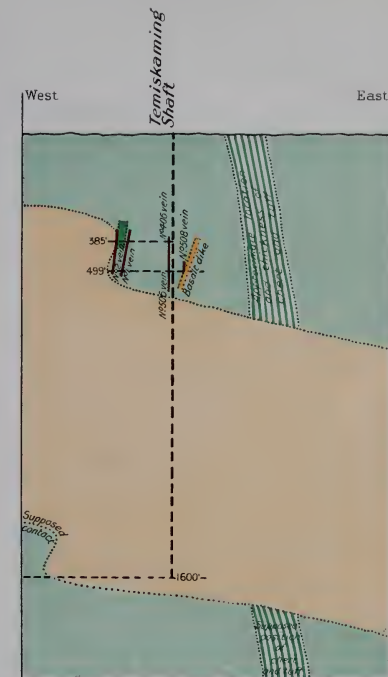
To accompany Ontario Department of Mines Report, Volume XXXI, Part 2, 1922, by Cyril W. Knight on The Cobalt Silver Area.

Scale, 400 Feet = 1 Inch





Vertical Section D-D, through main shaft of Temiskaming mine.



Vertical Section E-E, through Temiskaming (Gans) mine 725 feet south of main shaft of Temiskaming.

Explanation of Colours

PRECAMBRIAN	Keweenaw		Basalt dike about one foot wide, shown on Section E-E.
			Vein.
			Nipissing diabase sill.
	Algonian		Granite, represented by a great block of Lorrain granite which was caught up by the Nipissing diabase sill. Section A-A, 450-ft. level.
			Lamprophyre dike, hornblende diabase.
	Keewatin		Finely bedded chert, tuff or greywacke ("iron formation").
			Basaltic lava impregnated with iron pyrites. This pyritic zone is generally present, but is shown on only two Sections, namely C-E and D-D.
			Basalt with pillow structure in places.

Notes

The locations of these Sections are shown on the Beaver and Temiskaming Mines sheet 31a-1.

The collar of Beaver shaft is about eight feet below collar of Temiskaming shaft.

The 1600-ft. level of Beaver and Temiskaming was not accessible during the time of examination in the year 1920.

BEAVER AND TEMISKAMING MINES

ONTARIO

Report by Cyril W. Knight on The Cobalt Silver Area.

ch

800

1200



Fig. 10—Bed of Kerr lake after it was pumped out; Kerr Lake and Crown Reserve dumps; Diabase mountain in background.

found at the University mine at the west end of the dome. This structure is illustrated in the coloured section facing page 40. It will be noted that at the University the sediments of the Cobalt series below this dome are not folded into an anticline as they would be if the diabase sill had been folded into an anticline.

From the evidence found at the Crown Reserve and University mines it is probable that the diabase assumed its dome structure during the time it was intruded in a molten condition.

In South Lorrain a somewhat similar dome occurs in the diabase sill. This is discussed in the chapter dealing with South Lorrain.

Practically all of the silver-bearing veins in the Kerr lake area occur below the Kerr lake diabase dome. All of the productive veins, for example, in the University, Foster, Lawson, Crown Reserve, Kerr Lake, and Drummond have been found below this dome. The rocks below a similar diabase dome in South Lorrain have not, as yet, been productive of silver veins.

Thickness of Nipissing Diabase Sill

The thickness of the Nipissing diabase sill has now been definitely determined. It has been penetrated at four places, namely, the Temiskaming, Beaver, King Edward, and Colonial mines, where it was found to have a thickness of about 1,000 feet. At a fifth place, the North Cobalt property on the western outskirts of the town of North Cobalt, the diabase was penetrated to a depth of 700 feet without reaching the bottom of the sill.

These five points extend along a distance of over four miles, proving fairly conclusively the thickness of the sill.

In South Lorrain the thickness of the Nipissing diabase sill has not yet been determined.

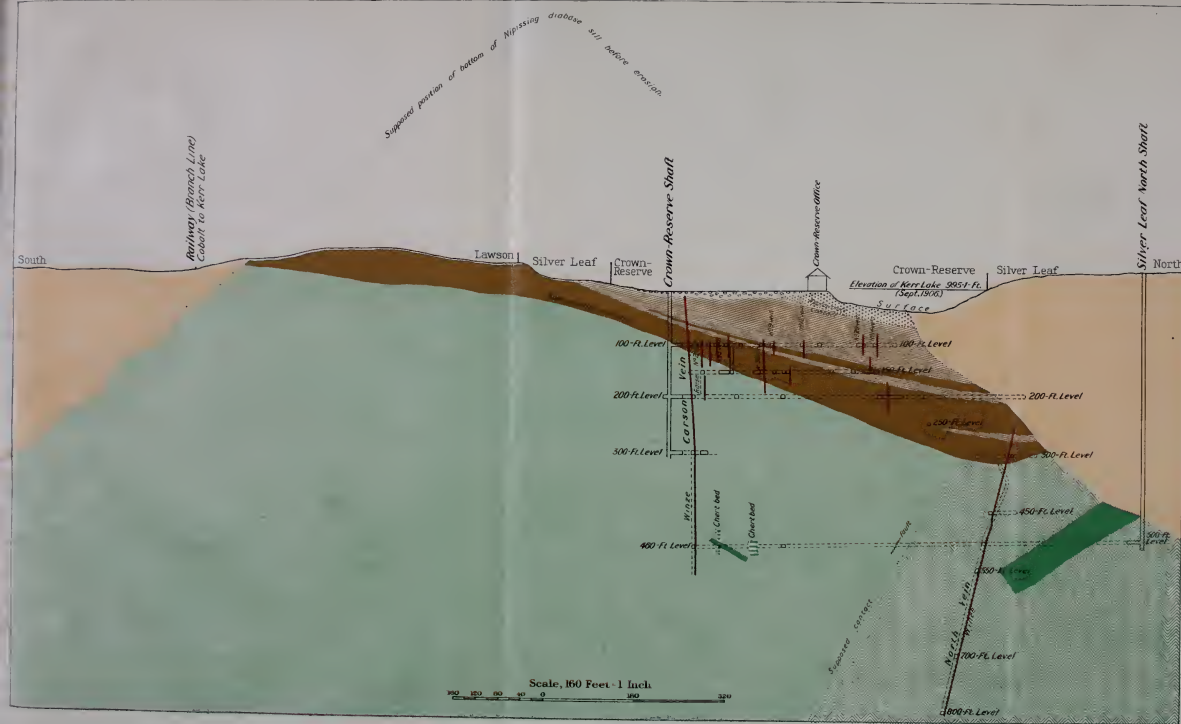
Sill Probably Intruded from Southeast

Although the direction from which the Nipissing diabase sill was intruded may not be an important question, it may be put on record that the sill was in all probability intruded from the south-east toward the northwest. The evidence for this statement was obtained at the Beaver mine. Here, at the top of the Nipissing diabase sill, a great block of granite about 150 feet long was found included, caught up, in the sill. To the southeast a few hundred yards a batholith of Algoman granite, similar to the inclusion, occurs, and it is evident that, as the diabase sill forced its way northwestward through the granite mass, it caught up a block of this granite during its progress.

Keewatin "Iron Formation"

The term Keewatin "iron formation" is frequently used throughout the report. The rocks belonging to the formation consist of chert, finely bedded, together with slate and greywacké. These beds have been tilted up into vertical or nearly vertical attitude. The formation contains very little iron oxides, although iron pyrites is common, so that the name "iron formation" is, perhaps, a misnomer. But similar rocks occur elsewhere in the Province of Ontario and in the Lake Superior region interbedded with bands of iron ore. Hence the cherty beds and associated slate and greywacké are usually called "iron formation." It has frequently been met with in the mine workings which have penetrated below the Cobalt series into the underlying Keewatin.

The formation is of some importance in relation to the silver veins at Cobalt, as it has guided the course of certain veins; that is to say, some of the



Explanation of Colours

Filled Ground, Drift

Vein

Nipissing diabase sill

Quartzite

Stale-like greywacke

Conglomerate, Greywacke

Lamprophyre dikes

Quartz-Gabbro (Halleyburian?)

Chert beds with iron pyrites and carbonaceous material

Basalt

Fault

Geological boundary

Explanatory Notes

Section showing mine workings supplied by Crown-Reserve Mining Co.

Geologically surveyed by Ontario Department of Mines in 1920.

The Keewatin basalt along the contact between the Keewatin and Cobalt Series is much decomposed, and the contact between the two series is not a sharply defined one. This is especially true on the 100-ft. level at the Carson vein.

Drawn for Photolithography by H. C. Smith

Sheet 31a-7

VERTICAL SECTION THROUGH CROWN-RESERVE SHAFT AND SILVER LEAF NORTH SHAFT

To accompany Ontario Department of Mines Report, Volume XXXI, Part 2, 1922, by Cyril W. Knight on The Cobalt Silver Area.

veins have followed the strike and dip of the "iron formation." This subject is referred to elsewhere.

Two of the most prominent bands of "iron formation" in Cobalt may be mentioned. One of them occurs in the deep bay of Sasaginaga lake. This bay extends eastwardly into the Trethewey property. The "iron formation" here consists of a bed of slate about 300 feet thick. On the south side of the bed there is a band of finely bedded siliceous material which passes into the slate. The formation was encountered in the workings from No. 6 shaft of the Trethewey below the Cobalt series. The other prominent bed of "iron formation" occurs in the depression under Clear lake; it extends eastwardly into the Townsite property. The bed consists mainly of chert and slate and appears to be wider than the bed at Sasiganaga lake.

There are several other beds of "iron formation" in this area. It may be added that it is difficult to distinguish the Keewatin "iron formation" from similar beds in the Timiskaming series. For instance, the vertical beds of chert or slate met with in the Genesee mine, below the Cobalt series, have been classed with the Keewatin "iron formation." It is reported, however, that "pebbles" have been found in these beds. If well defined "pebbles" do occur, it is more likely that the formation at the Genesee belongs to the Timiskaming, since the occurrence of true pebbles in the Keewatin iron formation is unknown at Cobalt.

Minerals Occurring in the Veins

The most important mineral in the veins is native silver. Other silver-bearing minerals are dyscrasite, argentite, and pyrargyrite. The ores of the metal cobalt are mainly smaltite and cobaltite. The gangue is chiefly calcite.

Miller gives the following list of minerals.¹

- I.—Native Elements:
Native silver, native bismuth, graphite.
- II.—Arsenides:
Nicolite, or arsenide of nickel, NiAs ; chloanthite, or diarsenide of nickel, NiAs_2 ; smaltite, or diarsenide of cobalt, CoAs_2 .
- III.—Arsenates:
Erythrite, or cobalt bloom, $\text{Co}_3\text{As}_2\text{O}_8 + 8\text{H}_2\text{O}$; and annabergite, or nickel bloom, $\text{Ni}_3\text{As}_2\text{O}_8 + 8\text{H}_2\text{O}$; scorodite, $\text{FeAsO}_4 + 2\text{H}_2\text{O}$.
- IV.—Sulphides:
Argentite, or silver sulphide, Ag_2S ; millerite, or nickel sulphide, NiS ; argyropyrite? stromeyerite? (Ag, Cu) $_2\text{S}$; bornite, Cu_5FeS_4 ; chalcopyrite, CuFeS_2 ; sphalerite, ZnS ; galena, PbS ; pyrite, FeS_2 .
- V.—Sulpharsenides:
Mispickel, or sulph-arsenide of iron, FeAsS ; cobaltite, or sulph-arsenide of cobalt, CoAsS .
- VI.—Sulpharsenites:
Proustite, or light red silver ore, Ag_3AsS_3 ; xanthoconite? Ag_3AsS_4 .
- VII.—Antimonides:
Dyscrasite, or silver antimonide, Ag_3Sb ; breithauptite, NiSb .
- VIII.—Sulphantimonites:
Pyrargyrite, or dark red silver ore, Ag_3SbS_3 ; stephanite, Ag_3SbS_4 ; polybasite? $\text{Ag}_9\text{SbS}_{12}$; tetrahedrite, or sulph-antimonite of copper, Cu_3SbS_7 ; freibergite? (silver-bearing tetrahedrite).
- IX.—Sulphobismuthides:
Matildite, AgBiS_2 ; emplectite, CuBiS_2 .
- X.—Mercury:
Amalgam?
- XI.—Phosphate:
Apatite.
- XII.—Oxides:
Asbolite; heubachite?; heterogenite?; arsenolite; roselite?
- XIII.—Veinstones:
Calcite, dolomite, aragonite, quartz, barite, fluorite.

¹Guide Book, Sudbury, Cobalt, South Lorrain, Kirkland Lake, Porcupine and Timagami, Ont. Dept. Mines, 1923, p. 98.

In addition to the minerals in the above list, H. V. Ellsworth has identified the following: löllingite (FeAs_2), rammelsbergite (Ni As_2), chalcocite (Cu_2S), symplectite ($\text{Fe}_3\text{As}_2\text{O}_8 + 8\text{H}_2\text{O}$).¹

T. L. Walker has identified the mineral cosalite ($2\text{PbS} \cdot \text{Bi}_2\text{S}_3$) from the Columbus mine at Cobalt.²

T. L. Walker and H. V. Ellsworth identified in 1914 the mineral temiskamite (arsenide of nickel) from the Moose Horn mine, Elk lake.³

Mr. Hugh Park, general manager of the Nipissing mine, gave to Willet G. Miller, Provincial Geologist, a specimen of the rare mineral sphærocobaltite, the proto-carbonate of cobalt (CoCo_3) from the Nipissing mine. The mineral has a delicate rose-red colour.

Mr. C. A. Knittel detected minute quantities of platinum and palladium in anode slimes resulting from the electrolytic refining of silver recovered by smelting ores from Cobalt.⁴

Epsomite ($\text{MgSO}_4 + 7 \text{H}_2\text{O}$).—In some of the old workings of the mines at Cobalt the writer found here and there a coating of white material. This coating consists of a fine net-work of white, hair-like, fragile needles, which vary in length from fractions of an inch to as much as two inches or more. The width of the needles may be from a fiftieth to one-hundredth part of an inch; possibly some of them may be as thin as cobwebs.

This net-like coating is sometimes half an inch thick and occurs on the floors, walls, and roofs of the workings, although mainly on the floors. As far as could be observed the material occurs where the workings are dry.

A sample of the mineral, which without doubt was deposited after mining had begun, was submitted to W. K. McNeill, Provincial Assayer. Mr. McNeill found the material to be epsomite, the hydrous sulphate of magnesium. The sample analyzed was obtained from the City of Cobalt mine on the third level, in a drift south of the "galena" fault.

Origin of Ores—Primary Character of Native Silver

It is now generally accepted that the ores have been deposited from mineral-bearing solutions which were given off by the Nipissing diabase. Miller was the first geologist to suggest this origin. The theory has stood the test of two decades, although numerous papers have been published espousing the secondary hypothesis.

Miller's views, and the views of certain other writers, regarding the origin of the ores are quoted below.⁵

The material in these veins has, in all likelihood, been deposited from highly heated and impure waters which circulated through the cracks and fissures of the crust and were probably associated with—followed—the Nipissing diabase eruption.

The waters are said to be associated or connected with the diabase eruption in the sense that they probably represented the end product of the eruption. In many volcanic regions hot springs are present long after the rocks have been solidified. In the Cobalt area the fissures

¹Ont. Bur. Mines, Vol. XXV, 1916, pt. I, p. 200.

²University of Toronto Studies, Geological Series No. 12, 1921, by T. L. Walker.

³T. L. Walker, Am. Jour. Sci., 1914, Vol. 37, p. 120.

⁴Jour. Can. Inst. Chem., Vol. 6, 1922, Aug., pp. 179-180.

⁵The Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming, by Willet G. Miller, Ont. Bur. Mines, Vol. XIX, pt. II, p. 8.

Guide Book No. 7, Int. Geol. Cong., 1913, issued by Ont. Bur. Mines, pp. 91-95.

and joints now occupied by the ores were probably produced by the gradual shrinkage in cooling of the diabase, the ores being deposited by the waters which represented the last stage of vulcanicity.

It is rather difficult to predicate the original source of the metals—silver, cobalt, nickel, arsenic and others—now found in these veins. They may have come up from a considerable depth with the waters or they may have been leached out of what are now the folded and disturbed greenstones and other rocks of the Keewatin. Analyses of various rocks of the area have not given a clue as to the origin of the ores. However, the widespread occurrence of cobalt veins in the diabase, or in close association with it, shown by discoveries during the last seven or eight years, throughout a region three thousand square miles or more in extent, appears to be pretty conclusive proof that the diabase and the ores come from one and the same magma.

After the intrusion of the Nipissing diabase sill, which, on the whole, dips at a low angle from the horizontal, and penetrates both the Cobalt series and the Keewatin, disturbance, probably due chiefly to the contraction of the sill on cooling, caused fissures and joint-like cracks to be formed. These openings were made in the rocks of the hanging-wall of the sill, in those of the foot-wall, and in the sill itself.

Ore-bearing waters working through or along the zone of weakness produced by the sill deposited their burden in the fissures and cracks. The minerals first to be deposited were essentially cobalt-nickel arsenides, and related compounds, and dolomite or pink spar. The fissures and cracks were ultimately filled with these minerals. Then there was a slight disturbance of the veins, reopening the ore-filled fissures and cracks, or fracturing the material deposited in them.

In the interval, between the filling of the fissures and cracks with cobalt-nickel ores and the fracturing of the veins thus formed by a secondary disturbance, the character of the material carried by the circulating waters had changed. Silver was then the characteristic metal in solution and it was deposited, along with calcite, in the cracks and openings in the fractured veins. There may have been some silver deposited in the earlier period of vein filling and doubtless cobalt-nickel minerals were deposited after the secondary disturbance, but the latter minerals belong characteristically to the first generation and the silver minerals to the second.

Certain writers on the Cobalt ores have expressed the opinion that the silver represents "secondary enrichment," meaning that it has come from the decomposition of compounds of the metal in the veins that were deposited at approximately the same time as the cobalt-nickel minerals. The present writer believes that at least by far the greater part of the native silver is of primary origin. The recent interesting experiments of Messrs. Chase Palmer and Edson S. Bastin,¹ on the precipitation of silver from solutions by cobalt-nickel minerals, appear to confirm the opinion that the native silver is a primary deposit, and did not come from the decomposition of silver compounds in the veins. The work of these gentlemen shows that where silver solutions come in contact with cobalt-nickel minerals the silver is deposited rapidly and essentially as native silver. Since there is much calcite in the veins with the native silver, it would appear that the metal was carried in solution as a carbonate, or double carbonate. Under ordinary conditions of temperature and pressure, silver carbonate is slightly soluble in water. For example, sufficient of the carbonate can be dissolved in an ordinary beaker of water to make a distinct precipitate of metallic silver when cobalt-nickel minerals are placed in the beaker.

It has been proved, by the experience gained in mining at Cobalt, that the presence of rich silver ore is dependent on proximity to the diabase sill. Over much of the productive area, not only the upper wall of the sill but the sill itself and more or less of its foot-wall have been removed by erosive agencies. Owing to little of the upper or hanging wall remaining in the productive area, most of the ore has come from the foot-wall of the sill, or from what was the foot-wall before erosion took place. In these veins, in the foot-wall of the sill, it is the exception to find rich silver ore extending more than two or three hundred feet below the surface. Most veins are productive to a lesser depth. After rich silver ore disappears, with increase in depth, cobalt-nickel ore frequently continues downward in the veins. This seems to be due chiefly to the strong precipitating effects that the cobalt-nickel minerals had on the silver in the waters that worked downward beneath or along the sill. The silver was deposited before it reached a great depth. In certain cases, where veins with cobalt-nickel minerals contain no rich silver ore, or in which the silver extends to a comparatively shallow depth, the absence of the precious metal is to be accounted for by the fact that such veins, or parts of veins, escaped fracturing during the secondary disturbance, thus not affording openings for deposition from the silver-bearing solutions.

Frequently, below the rich silver-bearing parts of veins, well crystallized argentite and hair silver are found in vugs. These minerals may represent secondary deposition of a little of the silver that has been dissolved from the upper part of the veins and carried downward.

Characteristically, the native silver of the area is impure, chiefly from the presence of antimony and mercury. Samples of well crystallized silver and certain veinlets of the mineral that have been examined are free from these impurities. Such silver is probably of secondary origin.

When native silver is precipitated by its solutions coming in contact with cobalt-nickel minerals, compounds of nickel and other metals go into solution. Hence, it is not surprising to find in the Cobalt veins minerals or compounds of the baser metals that appear to have been deposited during the later period of vein filling.

¹Econ. Geol., March, 1913.

Regarding the primary origin of the silver Edson S. Bastin concludes as follows:¹

Field and office studies of the ores of the Frontier mine show that nearly all of the native silver is a late primary mineral. Native silver is the principal valuable mineral of the ores. Most of it was deposited late in the primary mineralization. As the nickel and cobalt arsenides prevailingly show their own characteristic crystal faces against the silver the latter can not have replaced them. What appear at first sight to be replacement veins of silver and calcite traversing the arsenides are shown to be fillings of minute rifts developed during crystallization.

J. Mackintosh Bell has found that some of the silver in the Keeley mine is secondary. Regarding this secondary silver Bell concludes:²

What little microscopic work that has been done on the Keeley ores serve to corroborate the evidence, derived from analyses and gained more particularly from the careful accumulation of geological data, that a substantial part of the silver in certain of the rich shoots of the Keeley is secondary and derived from the impoverished highly oxidized upper portions of the veins. In making this statement the writer does not attempt to combat the now generally accepted theory as to the hypogene origin of the primary ore in veins of the cobalt type, to which those of the Keeley mine clearly belong. Much of the Keeley ore is probably purely primary and has gained no enrichment from descending solutions, but in other parts of the mine, where, indeed, the richest ore has been found, there would seem no reason to doubt the existence of widespread changes, which have materially altered and enhanced the value of the primary mineralization.

The views, regarding the origin of the ores, of an eminent geologist of his day, the late S. F. Emmons, are of interest in an historical way. Emmons, in 1910, considered that the silver was of secondary origin, and that the veins as they are found to-day are but the roots of veins that once could have been measured in thousands, rather than in hundreds of feet in depth. It may be added that his ideas have not been generally accepted.³

Doubtless most of you are more or less familiar with the general geological relations of the Cobalt district as given by the Canadian geologists. My own examination of the district has been too brief and cursory to justify any criticism of their determinations, which I therefore accept as far as the areal geology is concerned. The ore deposits are, however, of so remarkable a nature and so utterly different from anything seen within the boundaries of the United States that I have thought it might be interesting to you to hear what particularly impressed one who has had considerable experience in the study of the latter.

I could find no evidence that the silver had been introduced from below by a later accession of metal-bearing solutions, as seems to have been implied, if not explicitly stated, by those who have written on the subject, and I am inclined to believe that the second period of fracturing has served simply to furnish channels for descending silver solutions. I further believe that the reason that in the early veins the very rich ores did not extend far into the underlying Keewatin is to be found less in the fact that the Keewatin is unfavourable to the formation of fissures, than because the downward limit of secondary enrichment had been reached about at that depth. The change from rich to poor ore is certainly a remarkably abrupt one. In the No. 3 Kerr Lake mine, it occurs within 20 ft. or so, and in the No. 7 vein at the shaft it has been said that within two feet the ore dropped from 2,000 to 20 oz. The depth at which this change takes place is extremely variable. There are cases in which it has occurred within a few feet of the surface, and as already stated in the No. 3 Kerr Lake vein it is at a depth of over 300 ft. That denser, more plastic rocks may have an unfavourable influence, since in them there is less likelihood of cracks that are sufficiently open to admit the descending solutions, is quite probable, but there does not seem to be any general association of this condition with the bottoming of the bonanzas. I have in mind a single case. In the north-south portion of the No. 7 Kerr Lake vein, the bonanza seemed to stop at a band of dense black indurated slate which dips northward with the other sedimentary formations, but is above the so-called Huronian (Cobalt series) conglomerate, already spoken of as resembling a tillite. In the northwestern part of the claim, however, where this slate band has not been distinctly recognized, the bonanza has already gone down 50 ft. below the horizon the slate should occupy, and has reached a depth of 190 ft., whereas at the shaft it stopped within 100 ft. of the surface. At other points observed there seemed to be no change of rock associated with the bottoming of the bonanza zone. The microscopic study of polished specimens of the same vein in and below the bonanza discloses, as the main difference, the absence in the latter of the minute cracks traversing the vein material that characterize the former, and that evidently have served as channels for the introduction of the silver.

¹Primary Native Silver Ores of South Lorrain near Cobalt, Ontario, by Edson S. Bastin, Geol. Soc. Am., Ann. Meeting, 1923.

²Deep-seated Oxidation and Secondary Enrichment at the Keeley Silver Mine, by J. Mackintosh Bell, Econ. Geol., Vol. 18, Oct.-Nov., 1923, pp. 684-694.

³Read before the Geol. Soc., Washington, January 26, 1910.

Mr. Van Hise has stated, as a general truth, that openings in the zone of fracture of the rocky crust gradually decrease in size as depth increases, and doubtless many of you have had occasion to observe, as I have, cases where the opening of a given fissure vein decreases very perceptibly as distance from the original surface increases, and that a fissure-opening that may have a width of many feet in its upper part, if followed to sufficient depth, is found to end in a series of very small cracks whose width is to be measured in inches rather than in feet. It would seem, therefore, that the natural conclusion to be drawn from the extreme narrowness of the fissures in the Cobalt region is that they were originally formed under the pressure of a great weight of superincumbent rock or at great depth below the then existing surface; hence that the greater part of these original fissures has been eroded away, and what we see to-day are merely the roots of veins that once could have been measured in thousands rather than hundreds of feet. The question then is, what evidence is to be found in the geological history of the region that would justify this conclusion? Let us search and see.

The geology of the region to the north of the Great Lakes and west of Hudson Bay has not yet been worked out in detail, but its general character is assumed to be a great plateau of low relief, composed largely of pre-Cambrian rocks in which are patches of early Paleozoic beds that have escaped erosion, presumably through being enclosed in synclinal troughs, in like manner as have the Triassic beds which are found to be infolded with the crystalline schists in the Piedmont region west of Washington. The veins, as has been seen, cut through both series of pre-Cambrian rocks as well as the igneous rocks that have been intruded into them, but so far as known did not penetrate the Paleozoic sediments, and are hence assumed to be of pre-Cambrian age. From the manner in which the exposures of the two unconformable members of the latter series are distributed, it is evident that there must have been a considerable period of erosion before the Paleozoic beds were deposited over them, though there seem to be no criteria for estimating the length of that period. Since these beds were deposited, however, and the region has been again raised above the sea, it has been exposed to sub-aerial degradation continuously up to Glacial times, which in itself is a much longer period than the entire existence of the ores of Mesozoic or Tertiary age, which constitute by far the greater part of the ore deposits of the Rocky Mountain region. The evidence afforded by the peculiar character of the phenomena of secondary enrichment at Cobalt furnishes, to my mind, a still more convincing argument in favour of the assumption that the veins, both primary and secondary, are extremely old and have been exposed to degradation for an immensely long period, for secondary enrichment and degradation are processes that go on *pari passu*, and in a given region are necessarily coordinated. It seems fair to presume, then, that the erosion and wearing away by the continental glacier was only the emphasizing of a similar process that had been going on, though at a slower rate, for much longer periods of time. Secondary enrichment of ore deposits proceeds in a sort of arithmetical progress. As the vein with its enclosing rocks commences to wear away, certain of its metallic contents, rendered soluble through oxidation, are leached down and redeposited at a lower level, which we call the zone of sulphide enrichment because the ore in that region is abnormally enriched. But this enriched zone is gradually brought nearer the surface by continued wearing away of the latter; hence increasingly richer material is carried down, and the zone of secondary enrichment is constantly increasing in richness; but the primary ore beneath this zone, which is not reached by the enriching solutions, remains constant and unchanged in the condition in which it was originally deposited. Thus there seems no limit to the amount of enrichment that may take place, provided sufficient vertical extent of original vein is provided, and enough time allowed for wearing it down to its roots.

C. R. Van Hise,¹ in 1907, believed that most of the silver was secondary and was deposited through the influence of descending surface waters bearing oxygen. His views are given more fully in Chapter V.

Secondary Silver

Regarding the secondary origin of silver in the veins at Cobalt, there is evidence in vein No. 64, Nipissing mine, that silver has been deposited at two different periods in the history of the vein.

During the first period in the history of this vein, No. 64, the primary silver minerals, native silver and certain other silver minerals and cobalt and nickel arsenides, were deposited. Then the vein, a very high-grade one rich in native silver, was slightly fractured and cracks a quarter or half an inch wide were formed in the vein at right angles to the wall-rock. Along the walls of these cracks, which are partly open and vuggy, were deposited crystals of calcite; and on top of these crystals of calcite there were deposited crystals of argentite, ruby silver, and stephanite. These crystals of argentite, ruby silver,

¹The Ore Deposits of the Cobalt District, Ont., by C. R. Van Hise, Jour. Can. Min. Inst., 1907, Vol. X, pp. 45-61.

and stephanite belong to the second period in the history of the vein. It is probable that this silver of the second period of deposition is secondary, and was leached out of the vein higher up and deposited in its present position. It may be added that the writer observed very little of this secondary ore.

Some of the silver at the Keeley mine in South Lorrain is also secondary. This is discussed in Chapter III.

Surface Geology

Keewatin Lava Flows.—The work of this report was designed essentially to obtain and publish a record of the geology of the underground workings of Cobalt and South Lorrain. Hence practically all of the time was spent in the mines. A few weeks were devoted, however, to surface work, particularly in the Keewatin rocks between Cobalt and Sasaginaga lakes.

The Keewatin rocks in this area consist of several beds of "iron formation" interbedded with basalt. The "iron formation" is made up of banded chert, slate, and greywacké. The whole series, basalts and "iron formation," rests in almost vertical position, with a steep southward dip, and a strike of a few degrees north of west. The total thickness is unknown, but it exceeds one mile.

The only explanation which the writer has to offer as to the origin of this series is that the basalts are lava flows, and that the "iron formation" beds are of sedimentary origin, interbedded with the lava flows. After the beds were formed the whole series was tilted up into vertical position.

The occurrence of amygdules in rare cases, and the general fine or medium grained character of the basalts suggest their volcanic nature. It must be admitted, however, that the evidence for believing that the basalts constitute a series of lava flows is not as clear and indisputable as is the evidence regarding the wonderful series of flows in Lightning River and Cook townships south and southwest of Lake Abitibi.¹

East of the north end of Sasaginaga lake there is a considerable area of fine-grained, grey felsite. It is not known whether this rock is a lava flow or an intrusion. Nor has its age relation to the beds of "iron formation" and basalts been definitely determined. The only clue of the age relationship was obtained in the Buffalo mine where a small dike of felsite cuts the "iron formation."

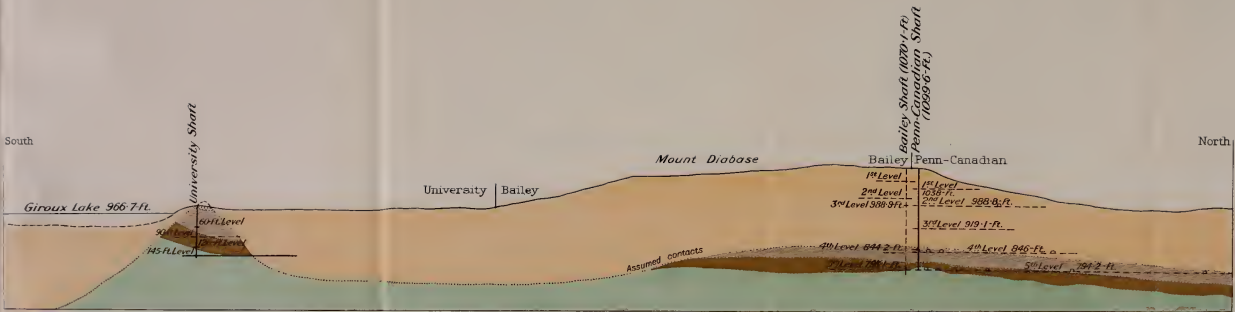
If a new surface map of Cobalt is ever published these beds of basalt and "iron formation," together with the felsite mass east of the north end of Sasaginaga lake, should be mapped in detail.

A little surface work was also done northwest of the town of North Cobalt. In a number of places there is evidence that a fault follows the valley which runs northwestward from the town of North Cobalt. In some pits, which were shown to us by Mr. Bennett, the fault breccia of the fault was observed, consisting of crushed rock cemented together by brown-weathering carbonate, probably dolomite or some closely related mineral. This fault probably extends southeastwardly along the drift-covered valley which lies immediately west of the Green-Meehan. The fault was met with in the long westward crosscut of the Ruby mine which is just west of the Green-Meehan.

In South Lorrain some days were spent on the surface, working out the form and structure of the Nipissing diabase. It was found to occur in the form of a sill of unknown thickness. The sill forms a great elongated dome. A description of this dome is given in that part of the report dealing with South Lorrain.

¹Abitibi-Night Hawk Gold Area, by C. W. Knight, A. G. Burrows, P. E. Hopkins, and A. L. Parsons, Ont. Bur. Mines, Vol. XXVIII, pt. II, pp. 9-17.

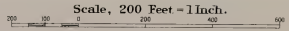
Black River Area, by D. G. H. Wright, Ont. Dept. Mines, Vol. XXX, pt. VI, pp. 33-42.



EXPLANATION OF COLOURS

PRE-CAMBRIAN	Keewenawan	Nipissing diabase
	Animikiean (Cobalt Series)	Quartzite
		Slate-like gneiss
		Conglomerate gneiss
	Keewatin	Unconformity

Note: The elevations of the Bailey and Penn-Canadian mine levels are shown in feet above sea level. The University levels are indicated in feet below the collar of shaft.



Sheet 31a-6

VERTICAL SECTION THROUGH UNIVERSITY AND PENN-CANADIAN SHAFTS
To accompany Ontario Department of Mines Report, Volume XXXI, Part 2, 1922, by Cyril W. Knight on The Cobalt Silver Area.

Correspondence Regarding Re-Survey of the Cobalt Silver Area

The following letter was written on December 20, 1919, to Dr. Willet G. Miller by the Timiskaming Mine Managers' Association, requesting the Ontario Government to undertake further geological survey work in the Cobalt silver area. As the letter resulted in the publication of this report it is printed here for purposes of record.

TEMISKAMING MINE MANAGERS' ASSOCIATION

Cobalt, Ontario, December 20, 1919.

W. G. MILLER, ESQ.,
Bureau of Mines,
Parliament Buildings, Toronto.

Re Geological Survey of Cobalt Silver District

DEAR SIR,—

At a recent meeting of this Association the matter was discussed regarding a further geological survey being made of the Cobalt district.

Being so instructed, we beg to communicate with your Department, placing this matter before you for your kind consideration.

You will appreciate that underground development has continued to verify the early conclusions of your Department.

With such further data as these developments have made available at various contact points, and by referring to stoping production records, it is very probable that the location of most important ore deposits will result from a thorough study of the geological conditions as are at present exposed in the Cobalt district. This is an essential work which would doubtless result in materially increased revenues to the Province, and the members of this Association will be pleased to be of any possible assistance to your Department in procuring the desired information.

This suggestion was one of several placed before Premier Drury and his colleagues during their recent visit to Northern Ontario, and we hope, after your consideration, that you may be able to arrange for the completion of this further geological survey, which will result in material and mutual benefit to the Province and the Cobalt mining industry.

Thanking you in anticipation, we are,

Yours truly,

TEMISKAMING MINE MANAGERS' ASSOCIATION,

(Sgd.) H. A. Kee, *President*.

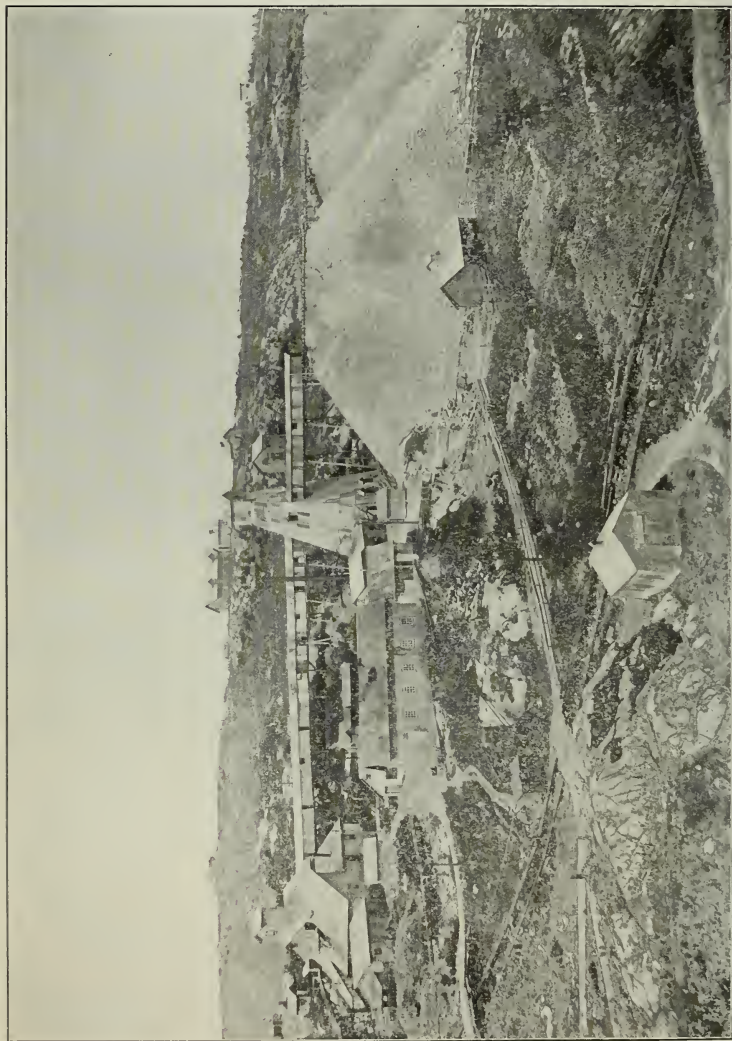


Fig. 11—Meyer shaft, No. 73, Nipissing mine. All of the ore from the Nipissing north of Cobalt lake is hoisted from this shaft.

CHAPTER II

GEOLOGY OF THE MINE WORKINGS

In following pages there will be found a description of the mine workings of nearly every property in the Cobalt area proper. An account of the mines in South Lorrain is given elsewhere in this report.

The order in which the properties are arranged is based on the number of ounces of silver which each company has produced. Thus, at the head of the list will be found the Nipissing mine, the output of which to the end of the year 1922 amounted to 65,700,579 ounces.

In describing the various levels of each mine it has been found convenient to begin with the lowest level and then deal with higher and higher levels. This order of description has been adopted because, as a general rule, the examination and mapping were begun on the lowest level of each mine.

The reader will be able more readily to follow the descriptions if he will use the plans in the pocket at the back of the report.

Mine managers at Cobalt who are familiar with every stope, drift, crosscut, and winze in their respective properties may find the descriptions lacking in many desirable details, particularly in reference to veins mined out previous to our examination. Little or nothing could be learned from an investigation of an empty stope, the ore-bodies of which have long since been worked out. It is hoped, however, that the general descriptions given will be of some value to mining men who have had neither the opportunity nor the time to examine all of the mines at Cobalt for themselves. Moreover, it may perhaps be added that later generations of engineers and geologists will read, at least with curiosity, if not with profit, the descriptions of what to them will be ancient mine workings!

In addition to the properties described in following pages there are many other prospects or mines which were not accessible, or which the writer did not have an opportunity to examine. They are consequently not described. Among these mines, descriptions of which are not given, are the following: Nova Scotia, Silver Cliff, King Edward, the mine workings under Peterson lake, the property known as "A.53" on Giroux lake, Shamrock, Badger, Cochrane, Waldman, Silver Bar, and others. Then, too, there are scores of claims on which more or less work has been done, such as the sinking of shallow shafts, open pits, trenching, and so forth, but which are not mentioned.

Those seeking information regarding these properties will find the reports of the inspectors of mines, in the annual volumes of the Ontario Department of Mines, of valuable assistance. It would have been possible to republish these descriptions in the present report; this, however, would have made the report of unwieldy bulk.

By making use of the general index to the annual volumes of the Ontario Department of Mines and of the index accompanying each volume, the reader will obtain references to information regarding many properties not mentioned in this report.

The aim of the writer has been to furnish descriptions and plans of all the principal producing mines. This, in large part, has been accomplished.

NIPISSING

The Nipissing Mines Company, Limited, has an authorized and issued capital of \$6,000,000, consisting of 1,200,000 shares of the par value of \$5. In respect of the total silver output, the dividends paid, the number of veins, and the number of productive acres owned, the company is the most important in the entire silver field.

To the end of the year 1922, the property had produced 65,700,579 ounces of silver, and had paid in dividends \$24,720,000. The company owns 846 acres in the heart of the area, of which 422 acres are underlain by rocks of the Cobalt series, 238 acres by Nipissing diabase, and 186 acres by rocks of the Keewatin series.¹

To the end of the year 1922, there were 28.2 miles of underground work, including drifts, crosscuts, raises, winzes, and shafts.

The writer has perused the eighteen annual reports of the Nipissing Mines Company, Limited. They are familiar to the engineers at Cobalt, but they may be commended to mining engineers elsewhere. They are models of accuracy, clearness, conciseness, and, above all, of integrity. The late Mr. R. B. Watson, the general manager, who was the dean among the mining fraternity at Cobalt, has signed all but the first three of the reports. They have been used freely in preparing the present report, and acknowledgment is herewith made.

Costs

The cost of producing silver in the year 1922 at the Nipissing is detailed in the following table, based on a production of 3,423,114.80 ounces and 82,025 tons of ore. The figures are given in the eighteenth annual report of the company.

Expenditure	Amount	Per ton ore	Per oz. silver
	\$	\$	Cents
Diamond drilling.....	31,544.22	.385	.921
Exploration.....	125,660.15	1.532	3.671
Development.....	103,600.96	1.263	3.027
Stoping.....	118,469.22	1.444	3.461
Hauling dumps.....	7,077.76	.086	.207
Assaying and engineering.....	12,995.28	.158	.380
Loading residue.....	547.39	.007	.016
Tailings disposal.....	640.33	.008	.019
Assorting and teaming Cobalt ore.....	13.09	.000	.000
Administration and office.....	50,948.71	.621	1.488
Camp maintenance.....	4,176.37	.051	.122
Insurance and taxes.....	126,264.74	1.539	3.689
General and legal.....	20,053.93	.245	.586
High-grade mill.....	136,354.96	1.662	3.983
Low-grade mill.....	343,567.91	4.189	10.037
Depreciation.....	32,571.24	.397	.951
Marketing product.....	21,882.71	.267	.639
Corporation, New York office, and travelling.....	19,441.54	.237	.568
	\$1,154,529.85	14.075	33.727
Less rents, exchange, and miscellaneous income.....	27,008.93	.329	.789
Total cost of production.....	\$1,127,520.92	13.746	32.938

¹Seventh Annual Report, Nipissing Mines Company, for year 1911, p. 10.

Development in Year 1922

An account of the development work which took place in the year 1922 has been given by Mr. R. B. Watson, the general manager, in the eighteenth annual report of the company, and is quoted in following paragraphs:—

All mining operations were considerably increased during the year. Work was carried on at six shafts, all widely separated. The total underground advance was the largest in several years; it was 63 per cent. more than in 1921.

The number of faces worked was 170, exclusive of stopes, of which there were 20.

Several new veins of moderate importance were discovered. The greatest increases of known ore, however, were obtained in the stopes of the older veins, particularly 64 and 490, and in the satisfactory development of vein 251 (south of Cobalt lake), found a year ago.

Shaft 19.—A large tonnage of mill-rock was mined from No. 6 open cut. The stope is increasing in length, and there is still a considerable area to be broken.

Vein 130 will also be mined through this shaft. It is smaller than No. 6, but the vein contains more high-grade ore.

Stoping operations were confined to the summer months, as the broken rock freezes during the winter.

Shaft 26 (Vein No. 26 north of Peterson lake).—A large production was obtained from this shaft during the early period of the property, but it has not been worked in recent years. The vein was extremely high-grade and was mined to a depth of 200 feet. It was one of the few veins of the district that produced any considerable amount of silver from the Keewatin formation.

The shaft was pumped out and repaired during the latter part of the year, and a large amount of exploration and development will be done. Particular attention will be given to an area near the lower contact of the diabase sill and the Keewatin.

Shaft 26 was worked before the company had a mill for the treatment of low-grade material; only high-grade ore was sought. It is probable that the old stopes contain unbroken low-grade ore which can now be recovered and treated at a profit.

Shaft 63.—All mining work was increased during the year. A few small veins were found, but the most important result of the year's work was the favourable development of vein 251.

A new level was started just above the Keewatin contact, 55 feet below the discovery level. A drift at the lower level shows a continuous ore-shoot 265 feet in length. The vein is 2 inches wide and has an average assay of 2,900 ounces. The present estimated ore reserves in vein 251 will probably be materially increased by vertical development, now under way.

After producing a large tonnage during the year, the ore reserves at shaft 63 show practically no decrease, and are about one-half of the total reserves at all shafts.

Shaft 64.—Stoping was actively carried on throughout the year. Notwithstanding a large production, the ore reserves show only a small decrease.

There is still an area to be mined which contains high-grade ore and which will also produce a large amount of mill-rock.

Shaft 73.—As in former years, this shaft produced most of the tonnage treated. After sending 42,000 tons to the mill, the reserves show an increase in tons and only a slight decrease in silver ounces.

Several new veins of fair importance were found. Faulted portions of a number of others were favourably developed and will produce a considerable tonnage in the future.

An important development was made on vein 490. While stoping a low-grade section of the vein, a high-grade shoot was encountered which more than compensated for withdrawals made during the year. The vein is 6 to 8 inches in width and assays several thousand ounces over a length of 60 feet.

Vein 490 has been a consistently large producer for several years and the present reserves show an increase over the previous year.

Shaft 80.—No work was done during the year.

Shaft 128.—No favourable developments were encountered, and the shaft was closed late in the year, the equipment being transferred to shaft 26 (vein No. 26).

Veins

In the description of the Nipissing veins in following pages only the more important ones are dealt with. As the veins on the property are numbered in the hundreds it is clearly impossible, in a report of this nature, to deal with all of them.

Ore Reserves

At the end of the year 1922, the ore reserves, according to the annual report of the company for the year 1922, consisted of 1,205 tons of high-grade ore

averaging 1,321 ounces of silver per ton, or 1,592,000 ounces; and of 57,338 tons of low-grade ore averaging 18 ounces of silver per ton, or 1,023,469 ounces. This makes a total of 2,615,469 ounces of silver.

In 1911, the area north of Cobalt lake, or east of the Coniagas, Trethewey, and Hudson Bay mines, became the most important producer and yielded three-quarters of the year's output. This area continued to produce a large proportion of the ore until 1921, when more than half the underground development took place on the southeast side of the lake, and the ore reserves were about equally divided between the two sides. In 1922, the ore reserves at shaft No. 63 were about one-half of the total reserves at all shafts.

Nipissing Mine Workings

In describing the Nipissing mine workings the ground may be divided roughly into two parts, that north of Cobalt lake, and that southeast of it. The ore is hoisted mainly in two shafts, namely, No. 73, north of the lake, and No. 63, southeast of the lake, although four other shafts of much less importance were in use in 1922, and there are a number of other shafts not now used.

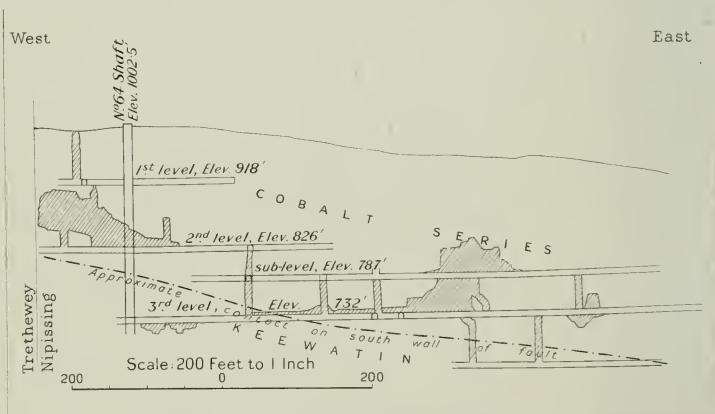


Fig. 12—Stope section on vein No. 64, Nipissing.

Mine Workings North of Cobalt Lake

The level plans of this part of the property are shown on sheet No. 31a-11.

The rocks consist of the Cobalt and Keewatin series. In the southeast corner of this part of the Nipissing, the Cobalt series attains a thickness of about 600 feet, its greatest known thickness in the Cobalt area proper.

The veins in this area belong to the same vein-system as do the veins on the Coniagas, Trethewey, and Hudson Bay. Vein No. 490 on the Nipissing, however, does not appear to have any direct connection with the Coniagas, Trethewey, or Hudson Bay veins.

There are four great systems of veins in this ground, namely: (1) vein-system No. 64, which is the eastward extension of veins on the Hudson Bay; (2) the Meyer vein-system, which is the eastward extension of the "main" vein on the Trethewey; (3) vein-system consisting of veins No. 80 and No. 100, which is the eastward extension of veins on the Coniagas; vein No. 80 has been called the

"Fourth of July"; (4) vein No. 490, which is at the east side of the area and strikes about north and south. Other veins of lesser importance occur.

Of these four vein-systems the Meyer, with its various branches, is the most important and intricate. The system extends across the entire property, and vein No. 98, the main branch of the Meyer vein, has been followed into the Chambers-Ferland a couple of hundred feet.

As the ore from many of these veins has been hoisted from shaft No. 73, it was not found possible to keep a record of the number of ounces of silver which each vein produced. Mr. Hugh Park, the manager, has, however, estimated that the production of the Meyer vein will amount to approximately 13,000,000 ounces of silver. This does not include any of the branch veins from the Meyer vein. The main branch, No. 98, of Meyer vein will produce approximately 4,000,000 ounces, according to Mr. Park.

The most northerly vein in this area is No. 64. It strikes eastward and dips to the south at angles of 70° to 90° , the flatter dip occurring on the lower workings. The vein occurs in a fault which is apparently a normal one, the south side having been faulted down 10 to about 25 feet, but it was not found possible to determine the exact amount of displacement. On the Hudson Bay property the displacement is not as much as it is on the Nipissing. There has been horizontal movement as indicated by the more or less horizontal scratches on the walls of the fault. The fault breccia varies in width from a few inches to as much as 8 or 9 feet in places, and the gouge is as wide as an inch or two. The vein is one of the largest and strongest in the Cobalt area, and it has been prospected to a depth of 1,075 feet on the dip of the vein. Several valuable ore-shoots have been opened up in the Cobalt series, but the ore-shoots did not extend into the underlying Keewatin. The ore-shoots in the Cobalt series had a width of two or three inches to as much as 42 inches. As the vein in the Keewatin was strong and carried low values throughout, it was considered advisable to explore it at depth, and the main shaft, No. 64, was therefore sunk to the 902-ft. level (Fig. 4). On crosscuts at 440 and 650 feet, the vein was soft and decomposed and showed little change from the condition on the third level. At the 902-ft. level, a crosscut 272 feet long was necessary in order to reach the vein, which was then drifted on for 454 feet. From this level an inclined winze was sunk, and 53 feet of drifting done on the lowest level. All this work at depth failed to develop any pay ore; the vein, while narrower, is still strong, but only assays from 5 to 20 ounces of silver per ton. At the time of the writer's examination in 1921 these deep workings were inaccessible; the description given is taken almost word for word from the annual reports of the company.¹

For several years little work was done on vein No. 64 in the Cobalt series and the ore reserves remained practically unimpaired. In 1921, stoping and development were increased, due to the completion of haulage facilities to the main hoisting shaft, No. 73. Substantial increases of ore reserves, both high-grade and mill-rock, resulted from this work. The average assay of the high-grade ore is about 1,000 ounces, but parts of the vein will assay much higher over widths of one to two feet. The vein is in the hanging-wall of the fault, and it generally rests on top of the gouge. In places it leaves the fault and runs parallel with it at a distance of two or three feet. In addition to the vein which is in the fault, there are veins which leave the fault and rise vertically upward for 40 or 50 feet (Fig. 14).

No ore-bodies have yet been found north of fault vein No. 64 on the Nipissing property.

¹Annual Reports of the Nipissing Mines Company, Limited, for the years 1909, 1913, and 1914.

The Meyer vein-system is one of the most important in the area, and, at the same time, one of the most interesting and intricate. In 1913 it produced the major part of the year's production. The Meyer vein is the eastward extension of what is known as the "main" vein on the Trethewey. The stope-section (Fig. 5) of that part of the vein on the Nipissing shows a length of 1,100 feet, and of that part of the vein on the Trethewey of about 500 feet, a total of 1,500 feet. Branching from the east side of Meyer vein there are about a dozen branch veins, the most important of which is No. 98, which extends eastward across the Nipissing and runs into the Chambers-Ferland for one or two hundred feet, where it breaks into two or three branches which practically pinch out.

Meyer vein is an excellent example of how ore-shoots at Cobalt follow down along the contact between the Keewatin and the Cobalt series, the ore being almost entirely in the Cobalt series. The ore-shoot rises about an average height of 110 feet above the Keewatin (Fig. 5). The Meyer vein on the surface is a barren calcite vein, three-quarters of an inch or less wide, except where the

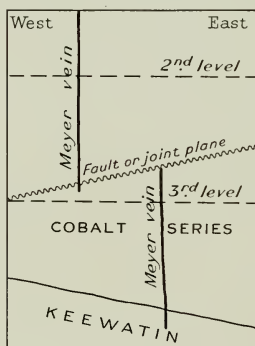


Fig. 13—Sketch showing relation between Meyer vein and fault, or joint, Nipissing mine.

high-grade shoot is exposed at the surface at the west end, owing to erosion. The general manager of the company, Mr. R. B. Watson, pointed out to the writer how the Meyer ore-shoot follows the Keewatin contact in the manner described; the stope-section referring to the Nipissing (Fig. 5) was kindly supplied by Mr. Watson, while the stope-section on the Trethewey was supplied by F. D. Reid of the Coniagas mine.

The east and northeast part of Meyer vein-system occurs above a slight depression or trough in the Keewatin on the third and fourth levels; how much of the depression is due to folding the writer is not prepared to say, but some folding has taken place and may be seen in the Cobalt series on the third level near the Keewatin.

The Meyer vein strikes a few degrees north of east and continues with this strike for about 400 feet when it gradually turns northeastward and finally northward.

On the third level the Meyer vein has been faulted, apparently, a distance of 40 or 50 feet, the part of the vein above the fault, or joint, having moved 40 or 50 feet to the west. This is dealt with further in describing the third level (Fig. 13).

Vein-system No. 80 and No. 100 consists of two veins known by those numbers; No. 80 has been called the "Fourth of July" vein. They have been important producers and are the eastern extensions of veins on the Coniagas. Between the first and second levels the management met with a fault which made the development on the second level for a while quite uncertain. The fault problem was satisfactorily solved by the management, and the veins were finally picked up below the fault.

Vein No. 490 is one of the best producers owned by the company. It is at the east side of the property, 50 to 100 feet from the Chambers-Ferland boundary line. The vein strikes north and south, but at the north end it turns eastward and enters the Chambers-Ferland, and at the south end it turns south-eastward and enters the Chambers-Ferland again. Most of the ore occurred on the Nipissing. In 1919, the vein had the largest ore reserves of any vein on the entire property. On the fourth and upper levels, the vein was barren. When the vein was first being explored, a winze was sunk from the fourth level on the vein to the Keewatin, but the results were not very favourable. It was found later that the winze went down at a poor spot with good ore on both sides. When drifting started on the fifth level, 431 feet below the collar of No. 73 shaft, results showed a great improvement; an ore-shoot 690 feet long was opened up, assaying 800 to 1,000 ounces of silver per ton. The vein averages five to six inches in width. On the sixth level, the ore-shoot has a length of 660 feet. In 1918, the average width of the stopes was ten feet; in that year the vein contained one-third of the total ore reserves.¹

The ore-shoots on vein No. 490 are like those in the Meyer vein, that is to say, they occur in the Cobalt series near the Keewatin contact. The ore-shoots of vein No. 490 do not rise more than about 150 feet above the Keewatin. Thus the vein is barren from the fourth level to the surface.

Workings on Vein No. 64

A description of the geological details of the mine workings north of Cobalt lake may now be given, commencing with vein No. 64. The lowest accessible level of vein No. 64 in 1921, when the examination was made, was the fourth level, which is reached from No. 73 shaft. All the ore is now hoisted from this shaft. A description of the workings below the fourth level has already been given.

Fourth Level.—(Elevation above sea level 654 feet at the station of No. 73 shaft.) The vein, No. 64, had up to the year 1921 been drifted on for about 500 feet. Part of the back of the drift had been timbered, apparently on account of the fact that the rock falls readily, causing the drift to be dangerous were it not for the timbering. Where the fault, No. 64, could be examined it was seen to consist of crushed rock from a foot to four feet wide, together with the usual gouge fractions of an inch wide. The drift was made in a fortunate position, because it shows that the fault is a normal one and that the rocks on the south side have been displaced at least eight feet. This may be seen in a short crosscut running south of the drift. The vein, which is one to fifteen inches wide, consists largely of pink calcite, together with lesser quantities of smaltite. In one place the smaltite appears to be younger than the pink calcite, because the smaltite occurs in irregular stringers cutting the calcite.

Third Level.—(Elevation above sea level 732 feet at No. 64 shaft.) The west part of the level had two or three feet of water in it during the time of

¹Annual Reports of the Nipissing Mines Company, Limited, for the years 1916, 1917, 1918, 1919.

examination in August, 1921. The raise east of the shaft, however, between the third and second levels was accessible from the second level, and in it we were able to find that the contact between the Keewatin and the conglomerate of the Cobalt series was about 14 or 15 feet above the third level on the south side of the fault. The contact on the north side is, of course, higher up the raise, but how far we could not determine. It is certainly below the sub-level, next to be described.

The winze from this level down to the fourth level was also accessible; the Cobalt series occurs for eight feet below the third level, and the remaining part of the winze down to the fourth level is greyish-white felsite.

Sub-level.—(Elevation above sea level 787 feet at No. 64 shaft.) The workings on this level consist of a drift, 650 feet long, following the vein. Towards the east end, the vein has been stoped from the third level up to and a little above the sub-level.

The sub-level is reached by a ladderway on the second level; this ladderway is about 160 feet east of shaft No. 64.

The vein on the sub-level is a wide one, in places two feet. It consists largely of pink calcite. At one place it shows a width of ten inches of smaltite. The vein occurs on the south side of the fault and closely follows it, except here and there where it may be a foot or two south of the fault.

In the stope, there had formed in the vein, in places, cracks at right angles to the walls of the vein; these cracks contained calcite crystals in vugs, and growing on top of the calcite crystals were crystals of argentite, stephanite, and ruby silver. The argentite, stephanite, and ruby silver are thus secondary, and clearly younger than the silver in the vein. There is, therefore, evidence that silver was deposited at two different periods in the history of vein No. 64. The subject of secondary silver is further dealt with on pages 39 and 40 of this report.

In places the vein contains much iron sulphide now altered to limonite. At one place on the level, the fault breccia is so soft that it has fallen down slowly from the back of the drift for 20 or 25 feet.

The ladderway, referred to above, leading from the second level to the sub-level, was examined. It shows a vein almost vertical, but dipping about 80° south. On the sub-level this vein is three or four inches wide. It apparently runs into the fault 15 or 20 feet below the sub-level, the exact distance not being determined on account of the timbers.

Second Level.—(Elevation above sea level 826 feet at shaft No. 64.) The fault on this level consists of one to two feet or more of fault breccia, on each side of which is a gouge an inch or less wide. The gouge consists of clay and finely-crushed rock. The vein rests on the upper gouge of the fault; it is, in places, two feet wide. It consists mostly of calcite, but there are veins of smaltite or niccolite. If the vein is followed along the drift, it will be seen that in places it leaves the fault and runs parallel with it, at a distance of two or three feet to the south.

Here and there in the fault, as on other levels, there are rusty streaks which probably resulted from the decomposition of iron pyrites, galena, or zinc blende.

At the west end of the stope on this level there is an excellent place to examine the vein and the relation of the vein to the fault. Here the party wall between the Nipissing mine and the Hudson Bay mine was still left standing in August, 1921. The fault may be seen dipping steeply to the south. Rising vertically from the fault there are three or more veins of smaltite and niccolite (Fig. 14). It was not ascertained how high these veins rose, but on the Hudson Bay side

of the wall one of them could be seen to rise 40 or 50 feet above the fault. A curious vein of smaltite or niccolite occurs in the fault breccia, crossing from the gouge on the upper side of the fault breccia, down through the fault breccia itself to the gouge on the footwall of the fault breccia.

Running north of vein No. 64, there is a long exploratory crosscut, 1,200 feet in length, which runs to the north end of the Nipissing boundary. The writer did not examine the north part of this crosscut. In a crosscut, 450 feet north of vein No. 64, a light-coloured grey felsite was met with at the west end. A fault was encountered in this west crosscut dipping 21° to the east.

Eighty feet north of vein No. 64, in the long crosscut referred to in the above paragraph, there is a fault striking apparently a few degrees north of west. This fault may be the eastward extension of "Y" fault on the third level of the Hudson Bay. Twenty feet farther north of this fault there is another similar fault which may correspond to fault "X" on the third level of the Hudson Bay. Both faults have a foot or two of fault breccia and fractions of an inch of gouge. They appear to be branches of fault No. 64.

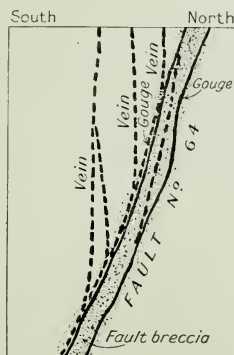


Fig. 14—Sketch, idealized, showing relation between fault No. 64 and veins; Nipissing mine, shaft No. 64, second level, west face of stope on boundary between Nipissing and Hudson Bay mines.

First Level.—(Elevation above sea level 918 feet at shaft No. 64.) There has not been much work done on this level; the vein has been drifted on for about 200 feet, and there is one short crosscut. No stopping has been done. The vein in the west part of the drift varies in width from a few inches to a foot; it averages about six or eight inches in width. A few feet east of the shaft, the vein pinches out, and from there to the east end of the drift, a distance of 90 feet, there is no vein exposed. In this barren area, the fault breccia has a width at one place of nine feet, with a gouge at each side of the fault breccia an inch or two inches wide.

Near the west end of the drift, at a crosscut, there is a pink calcite vein, a few inches wide, north of the fault about two feet. In places there is much rusty material in the fault. This rusty material probably results from the decomposition of iron pyrites, galena, or zinc blende.

In the shaft about 30 feet below the first level, there is a bed of slate about 13 feet, more or less, thick; timber in the shaft prevented our obtaining its exact thickness. The bottom of the bed of slate is 30 feet below the level.

Meyer Vein-System, and Veins 544, 490, 80, and 100

These veins are worked almost entirely from shaft No. 73. A description of the workings, beginning with the lowest, the ninth, may now be given. Reference to sheet No. 31a-11, in the pocket at the back of the report, will make the descriptions more readily followed.

Ninth Level.—(Elevation above sea level 434 feet.) With the exception of the deep shaft on vein No. 64, the ninth level is the deepest on the Nipissing property in this area. The Cobalt series has a thickness of about 600 feet, which is the greatest known thickness in Cobalt. The level is reached by going to the bottom of the Meyer shaft, thence along the fourth level to winze No. 73-4014; thence down this winze 112 feet to what is known as the fifth level; thence southward along the fifth level about 750 feet to winze No. 544; thence down this winze 122 feet to the ninth level, which is 548 feet below the collar of No. 73 shaft.

On the ninth level, there are about 500 feet of drifts and crosscuts, mostly on vein-system No. 544, which is labelled on the geological plan as vein No. 73-92 and No. 73-97.

An interesting feature of the Keewatin floor is the fact that the floor dips to the west, whereas on the west part of this area on higher levels the Keewatin floor dips to the east. There is, therefore, a valley, or depression, in the Keewatin floor in this area, the axis of which strikes a few degrees east of north. The depression may be due, in part, to folding.

The vein strikes about parallel to the axis of this Keewatin valley, that is, a few degrees east of north. The vein is not a wide one, possibly averaging an inch or two, mostly of pink calcite. At the north end it contains considerable niccolite. There has been no stoping on this level. The vein is one of the deepest veins occurring in the Cobalt series in the entire camp.

There are at least five faults on the level. One of these appears to be important; this one occurs at the station and seems to almost parallel the strike of the contact between the Keewatin series and the Cobalt series, namely, a few degrees east of north. It dips at angles of 57° to 67° eastward. The fault contains a vein of pink calcite and quartz two or three inches wide, in places six inches or more wide. The only place at which we could obtain a hint as to whether the fault was normal or reverse was in a crosscut 95 feet south of the winze, running eastward. Here the fault may be seen dipping 61° eastward. Broken rock largely filled the crosscut at the time of examination, but it appeared from what could be seen of the fault that it is a reverse one. Judging from the dip of the bedding on this level and the level above, the displacement is 20 to 25 feet, approximately.

In addition to this fault, there are four other faults, one of which is shown on the plan. These four faults do not appear to be as important as the one described above. The fault at the north end of the workings dips at an angle of 42° to 48° to the west; it intersects the vein above the level, but does not appear to fault it. On account of these faults the rocks on this level are crushed and altered, making it difficult, around the winze, to determine accurately the contact between the Keewatin and conglomerate of the Cobalt series.

Eighth Level.—(Elevation above sea level 481 feet.) Vein-system No. 544 on this level has yielded a little ore, whereas it had not been a producer on the ninth level up to August 11th, 1921. The vein at the south part of the drift follows a fault dipping steeply eastward, but, at a distance of 85 feet south of the winze, at a crosscut, it leaves the fault, the fault running into the wall.

At the south end of the fault, the rock is crushed for a width of two feet, but the crushed zone and gouge may average perhaps three or four inches.

In the crosscut at the south end of the workings, there is a bed of finely banded greywacké dipping southwest at an angle of 18° .

Vein No. 73-804, at the southeast corner of the level, has been stoped to a small extent and has produced a little ore. The stope apparently extends south to the party wall, and the veins may thus extend into the adjacent Right of Way claim on the south; it is a small vein.

Summing up the results of the work on the eighth and ninth levels, it may be said that these levels were made to explore vein-system No. 544; the output of silver therefrom has not been important. The general manager reported that ore occurrences in the vein were erratic and that two branch veins produced small quantities of good ore.¹

Before describing higher levels it may be explained that there is no seventh level.

The sixth level is reached from winze No. 73-4014, about 750 feet north of winze No. 544, and will be next described.

Sixth Level.—(Elevation above sea level 511 feet.) The level consists mostly of a drift about 700 feet long on vein No. 490. The general manager reported in 1917 that the ore-shoot in the vein was 660 feet in length.

The Cobalt series forms a narrow belt running north and south and having a width of 30 to 70 feet.

An important fault, which has been named the "valley" fault, occurs on this level (Fig. 15). The fault strikes northward, and dips to the east at 59° to 77° . It is a reverse one, the rocks on the east side having been thrust up 75 feet, approximately.

Another fault occurs following the contact between the Keewatin and Cobalt series for some distance on the west; this fault dips eastward 38° to 60° .

The rocks are crushed and altered owing to these faults. For this reason the conglomerate and greywacké of the Cobalt series are difficult to separate from the Keewatin. It was found necessary to examine many thin sections of rock under the microscope, and even then the contact shown on the geological plan must be considered approximate. If more thin sections were taken and more time devoted, it might be possible, perhaps, to determine the contact more accurately. At the extreme north end, the contact between the Keewatin and conglomerate of the Cobalt series occurs about 13 feet above the floor in a raise leading to the fifth level. In another raise, just to the south, the contact is about 25 feet above the floor.

South of the winze, in the stope, the vein could be examined in August, 1921. It is a wide vein, in places showing a width of 8 or 10 inches of smaltite and niccolite. This vein occurs below the "valley" fault. It is younger than this fault, as will be explained presently.

About 11 feet below the sixth level there is a sub-level, consisting of a crosscut, which was flooded at the time of our examination. This sub-level was run some years ago, and little is known concerning it.

Fifth Level.—(Elevation above sea level 551 feet.) The level is reached from winze No. 73-4014. It is an extensive level, running north and south for about 1,800 feet, about paralleling the Chambers-Ferland boundary, in places a few feet distant.

Vein No. 490 has been followed for nearly 1,000 feet, and an ore-shoot 690 feet long disclosed, the vein assaying 800 to 1,000 ounces per ton across 5 to 6 inches.

¹Annual Report Nipissing Mines Company, Limited, for year 1920.

At the southeast corner of the workings, a small stope has been mined in vein No. 73-567. This vein extends into the Chambers-Ferland.

The "valley" fault (Fig. 15) occurs in a crosscut opposite winze No. 73-4014. The rock east of the fault is Keewatin, and west of the fault Cobalt series. In the back of the stope, below the level, the writer examined the fault for a distance of about 300 feet, and found a fault breccia 6 to 10 feet wide, consisting of badly crushed rocks. In the stope, the fault dips eastward at about 60° . Keewatin rocks appear to be on the east side of the fault, and Cobalt series on the west; but the rocks are so badly crushed that difficulty was found in distinguishing them. As on the level below, it is evident on the fifth level also that the "valley" fault is a reverse one, the Keewatin having been thrust over the Cobalt series about 75 feet (Fig. 15).

There is another fault, at the station of winze No. 73-4014, dipping 36° eastward. This fault gradually joins the "valley" fault some 20 or 25 feet below the level. Vein No. 490 passes through this fault (Fig. 15).

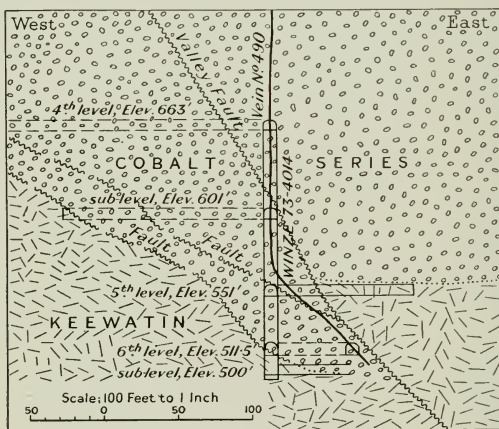


Fig. 15—Vertical section through vein No. 490, Nipissing mine, north of Cobalt lake, showing "valley" fault, and vein No. 490 passing through fault.

The age relation between the "valley" fault and vein No. 490 is shown in winze No. 73-4014, about 65 feet above the fifth level. The vein passes through this fault without having been faulted. Therefore, the vein is younger than the fault, as it has been shown that the displacement along the fault is at least 75 feet (Fig. 15). If the vein were older than the fault, it would have been faulted 75 feet.

Vein No. 490 is about vertical until it descends to within a few feet of the fifth level, when it flattens out and about follows the same dip as the "valley" fault (Fig. 15).

At the south end of the workings, west of winze No. 544, there is a bed of finely-bedded greywacké, 30 or 40 feet thick, which forms a horseshoe-like structure. The structure is suggestive of a syncline due to folding, as the bottom of the syncline shows the greywacké to be crushed and contorted for 15 or 20 feet or more. It may be that this bed conformed to a valley in the Keewatin,

which strikes east of north, and that the bed was slightly folded, the folding following the axis of the valley.

The contact between the Keewatin and Cobalt series is exposed in the workings south of winze 73-4014 in three crosscuts. There is a well-defined fault at or about the contact. In one of the crosscuts this fault is followed for 140 feet; the fault here contains a vein of pink calcite and quartz up to 8 or 10 inches wide, immediately below which is a striking seam of blue clay a fraction of an inch to an inch wide. The fault dips at an angle of 34° to 40° southeastward.

Sub-level between the Fifth and Fourth Levels.—(Elevation above sea level 601 feet.) This level, which is reached from winze No. 73-4014, was also mainly used to develop vein No. 490.

The general plan of the level consists of a crosscut about 1,500 feet long, with a northerly but variable strike. It parallels the Chambers-Ferland boundary in a general way. It roughly parallels the Keewatin contact to the west; there are several east-west crosscuts running out to the contact.

Vein No. 490 may be seen at the winze and in three crosscuts south of the winze. In the first of these crosscuts south of the winze, the vein consists of about 5 inches of niccolite and some native silver. The "valley" fault is also exposed in three crosscuts. The vein apparently crosses the "valley" fault about 25 feet south of winze No. 73-4014. This fault south of the winze shows 2 to 3 feet of crushed rock and a gouge an inch or two wide.

Another fault, dipping 29° to 49° eastward, follows roughly the contact between the Keewatin and Cobalt series, and in places contains a vein of barren pink calcite and quartz, one to eighteen inches wide. North of the winze the fault turns northeastward and splits at the northeast end.

At the north end of the crosscut, the fault known as No. 64 was met with. It dips at 70° southward, and is about on a line with No. 64 fault disclosed in the workings from shaft No. 64. The fault consists, beginning on the south side, of the following: (1) six inches of soft, decomposed crushed rock fragments, with reticulating stringers of calcite fractions of an inch wide, together with stringers and disseminated grains of galena; (2) one and one-half to two inches of almost pure galena and a little copper pyrites; (3) eight inches of material similar to No. 1; (4) fifteen inches of slightly crushed rock; (5) two to six inches of crushed rock cemented with calcite stringers.

The rock on the north side of the fault is Keewatin felsite, and on the south side the Cobalt series. It is thus seen that the fault is a normal one in which the rock on the south side has been faulted down, how much is not known, but elsewhere in the mine the displacement is 10 to 25 feet.

Fourth Level.—(Elevation above sea-level 654 feet at shaft No. 73.) This level has developed the Meyer vein and its several branches. The level is connected with vein No. 64 at the north part of the workings. Vein No. 490 has been explored by a drift for 350 feet at the southeast part of the workings, but the vein has not been productive on this or levels above because the level is too high above the Keewatin contact.

The level shows the main Meyer vein extending into Keewatin and following, at the south part, a bed of Keewatin "iron formation" which consists of black slate and chert. The vein was not productive in the Keewatin.

The most important branch of Meyer vein is No. 98 which continues north-eastward and eastward, and extends into the Chambers-Ferland a short distance, where it practically pinches out. Vein No. 98 has half a dozen branch veins leaving it on the southeast side, and three or four leaving it on the northwest side. The stope on vein No. 98 averages approximately 10 or 15 feet in width.

There are three important faults on the level, namely, (1) fault No. 64, striking eastward, at the north part of the workings, in which vein No. 64 occurs; (2) the "valley" fault, striking a little east of north, at the east side of the workings; and (3) a fault which roughly parallels the valley fault at a distance of 100 to 200 feet to the west; this fault towards the north gradually converges with the "valley" fault, until about 200 feet north of shaft No. 98 the two faults are only 10 or 12 feet apart. At the south end of the workings this third fault follows the contact between the Keewatin and the Cobalt series for 300 feet, more or less, but towards the north it gradually leaves the contact until, at the north end, it is about 330 feet east of the contact. In places a vein of barren pink calcite and quartz is found in the fault; this vein is generally 2 or 3 inches in width, but in places as wide as 15 inches. This fault has been cut in a dozen places by drifts or crosscuts. It is of importance because it cuts off four of the veins, Nos. 420, 433, 419, and 426, which are southeastward branches of No. 98 vein. The stopes show how these four veins have been mined up to the fault, and are there cut off. Three veins have, however, been found above the fault; our examination did not determine whether or not these three veins were faulted portions of three of the veins below the fault.

The conglomerate on this level is remarkably coarse in many places, the boulders commonly being a foot or two in diameter. Quite often these boulders are seen on the floors of the workings, having fallen out intact from the sides or backs. Possibly one reason why the stopes in the Meyer vein-system are not wide, compared to certain Coniagas stopes, is on account of this coarse conglomerate. It was found on the Coniagas that the widest stopes are in the finer-grained conglomerate, not in coarse-grained conglomerate.

The contact between the Keewatin series and the Cobalt series shows a slight valley or depression in the Keewatin floor in one place. This depression occurs also on the level above, that is, the third level, on which level it is more pronounced. The Meyer system of veins appears to occur in the Cobalt series above this depression. Folding may, in some measure, have formed the depression.

Vein No. 64 has already been discussed in dealing with the workings from shaft No. 64.

Third Level.—(Elevation above sea-level 734 feet at No. 73 shaft.) From this level have been mined the Meyer vein and some of its branches, and No. 64 vein at the north end of the workings. Vein No. 490 was intersected in a long crosscut, at the southeast end of the workings, and followed for a few feet, but it was not productive on this level.

The valley or depression in the Keewatin, which was described on the fourth level, also occurs on the third, and the Meyer vein-system occupies, in a general way, this depression. Folding may have caused the formation of the depression, or it may be partly due to a trough or depression in the original surface of the Keewatin, later somewhat deepened by folding.

The Meyer vein extends up to a minor fault plane (Fig. 13), immediately above which it was found at a distance of 40 or 50 feet westward. The vein has the appearance of having been normally faulted, 40 or 50 feet to the west. The fault dips at angles of 8° to 15° to the west. Where we were able to examine the fault it contained neither fault breccia nor gouge; scratches were noted in it striking westward, the direction of the supposed movement. The fault, however, has more the appearance of a strong joint plane rather than a typical fault. It contains in places a calcite vein fractions of an inch wide.

There is a possibility that the Meyer vein may not have been faulted; perhaps the fracture in which the vein was found extended down to this well-

defined joint plane, and that, instead of continuing downward through the joint at that place, the fracture formed below the joint 40 to 50 feet eastward, and then continued down to the Keewatin.

Regarding these two points of view the writer must admit that he did not have an opportunity of examining the relationship of the vein to the supposed fault during the mining operations. The vein was mined out at the time of our examination. Those who were daily examining the working faces are best able to judge.

Vein No. 64 is described in that part of the report dealing with the workings from shaft No. 64.

Second Level.—(Elevation above sea level 816 feet at No. 73 shaft.) The second level is the most extensive level north of Cobalt lake, extending as it does almost the entire length of the property, about 3,700 feet. The workings connect with vein No. 64 at the north, with the Meyer vein at shaft No. 73, with vein No. 80 (the "Fourth of July") and vein No. 100. These two vein-systems, No. 80 and No. 100, were worked from No. 80 shaft. Vein No. 490 was also intersected in a long eastward crosscut, but it was barren, being too high above the Keewatin.

The workings from shaft No. 80 are about 29 feet below the workings from shaft No. 73.

At the station of No. 73 shaft, a prominent fault dips 21° to 30° southeastward; it has a vein of barren calcite about two inches wide, and some very red hematite. In the stope just west of the shaft above the level, the calcite vein in this fault is about 20 inches wide.

Vein No. 80 appears to pinch out in a few feet after it enters the Keewatin.

First Level.—(Elevation above sea-level 905 feet.) On this level the Meyer vein and veins Nos. 80 and 100 have been worked. The level is not an extensive one. The Keewatin does not occur.

The fault at the northeast part of the workings has been intersected in two places, in a drift and in a crosscut. The fault dips about 22° to 24° to the southeast and strikes northeastward. It consists of a fault breccia and gouge up to 12 inches or more wide. It cuts off a strong pink calcite vein which occurs at the northeast corner of the workings east of the Meyer shaft. This fault is shown on the map to connect with a fault which cuts the crosscut about 120 feet north of the "Fourth of July" shaft. It is not definitely known that the two faults are one and the same.

Veins No. 80 and No. 100 were originally worked from the "Fourth of July" shaft. They are the eastward extension of the No. 2 system on the Coniagas mine. They are now stoped out, but it was stated by the management that both veins were faulted, or apparently faulted, the parts of the veins above the fault having been moved some 4 or 5 feet to the northwest. The fault on which the movement took place is evidently the one described above.

Nipissing Mine Workings South of Cobalt Lake

The mine workings, grouped under the above heading, occur to the south and east of Cobalt lake. The plans are shown on Sheet No. 31a-13. The ore reserves in this area were in the year 1922 about one-half of the total reserves of the entire property.

Included among the important veins in this part of the Nipissing are No. 63 (Kendall), "Little Silver" vein-system, No. 251 (259), No. 96, No. 102, No. 109, and No. 99. These veins are south of the south end of Cobalt lake. In-

cluded among the important veins east of the lake are the following: No. 49, No. 122, and No. 26.

The company did not find it possible to keep a record of the ounces which each vein produced.

Vein No. 63, known as the Kendall, was considered to be the best vein found on the property up to the end of the year 1910,¹ but its output was subsequently far outstripped by the Meyer vein-system north of Cobalt lake.

The "Little Silver" vein-system was one of the first discovered in the camp in 1903. It has been an important producer.

The productive part of vein No. 251 (259) was discovered in 1921, and has developed during the last two years beyond expectations. The annual report of the company for the year 1921 states that the drift at the second level disclosed an ore-shoot 70 feet long with an average of three inches of ore assaying 3,500 ounces of silver. On the level below there is a continuous ore-shoot 265 feet in length, the vein showing two inches in width and an average assay of 2,900 ounces.²

In the year 1917, active stoping of veins Nos. 96 and 102 was begun, and results from this work were satisfactory and exceeded expectations.³ Vein No. 109 in the year 1919 had been opened up on two levels and showed at that time ore reserves of 675,000 ounces of silver; the best part of the ore-shoot on the tunnel level assayed 6,800 ounces of silver over a width of 2.5 inches for a length of 80 feet.⁴

Vein No. 99 was found late in the year 1918; it is a comparatively small vein, but is rich.⁵

In the early history of the company, vein No. 49 was discovered and created much excitement and great hopes. It had an unusual width and was very rich. Unfortunately, the depth of the Cobalt series in the vicinity of the vein was shallow, and the hope that the vein would be a great producer was not realized. The records published in the annual reports of the company for the years 1908, 1909, and 1910 show that the vein during these years yielded 859,102 ounces of silver; the Ontario Department of Mines has no record as to what was the total yield of the vein.

Vein No. 122 was discovered in 1909, and the fracture was traced for about 900 feet; it was, however, only productive at the west end. During the years 1909 to 1914 this vein, together with Nos. 53 and 54, produced 1,958,711 ounces of silver, according to the records of the company; practically all of this output was obtained from vein No. 122. The ore of vein No. 122 was rich, the average value of the high-grade in 1909 being 5,600 ounces of silver per ton. A large amount of exploration work has been done on this vein, but much of the work was not productive of results. Work on the vein ceased in 1914.⁶

Vein No. 26, near the north end of Peterson lake, was one of the veins worked during the early days of the company. It produced about 1,500,000 ounces of silver; operations at the vein ceased in 1910. The workings were, however, dewatered in 1922 and operations resumed. The vein was entirely in the Keewatin basalt, and it was one of the few producers of the entire Nipissing property which was productive in the Keewatin. At the time of examination

¹Annual Report Nipissing Mines Company, Limited, for year 1910, p. 11.

²Annual Report Nipissing Mines Company, Limited, for year 1922, p. 15.

³Annual Report Nipissing Mines Company, Limited, for the year 1917.

⁴Annual Report Nipissing Mines Company, Limited, for the year 1919.

⁵Ibid.

⁶Annual Reports Nipissing Mines Company, Limited, for the years 1909 to 1914.

the workings were inaccessible. The stope section (Fig. 16) furnished by the company shows that the stope narrowed in length at the bottom.

At the time of our examination, in the year 1921, a number of other workings were also inaccessible. At the east side of Cobalt lake, the workings at No. 81 shaft and No. 128 shaft were not accessible. The workings east of Cart lake at No. 150 shaft and the workings west of Cart lake at No. 86 shaft were also inaccessible. The information regarding these inaccessible shafts, and workings connected therewith, has been obtained from the annual reports of the company.

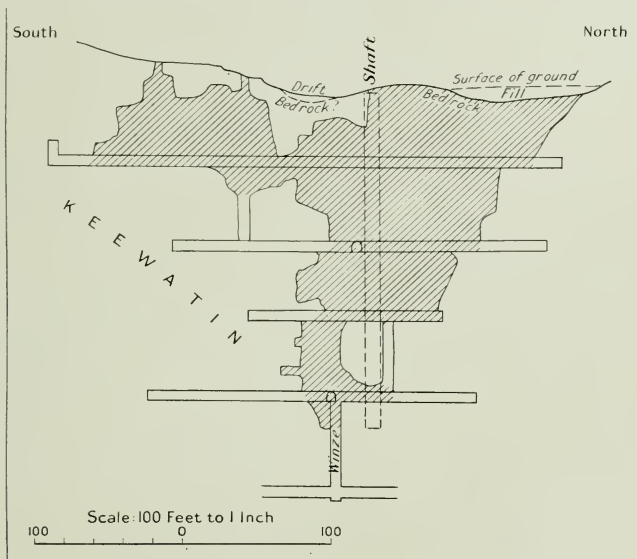


Fig. 16—Stope section of vein No. 26, Nipissing.

At shaft No. 81, near the east shore of Cobalt lake, considerable work was done on the Cobalt lake fault. Important ore-shoots had been found in this fault on the Cobalt Lake property, making it advisable to prospect the fault on the Nipissing property. The annual report of the company for the year 1916 states:—

Shaft 81 was sunk to the Kewatin and crosscuts were driven at 425 feet and 520 feet below the collar. There is a strong vein along the fault, at times considerable cobalt, and occasionally some high-grade ore. These occurrences of rich ore, however, are scattering; nothing that can be considered an ore-shoot has yet been found.

The annual report of the company for the year 1917 states:—

Development of the Cobalt lake fault continued throughout the year. An adjoining company found considerable ore in the fault just to the south of the boundary line. With the exception of a few tons of ore, however, no profitable values were discovered on the Nipissing side of the line. Some 4,200 feet of development work was done on the fault at 425 and 520 foot levels, including some exploration into the conglomerate at these levels. About 6,500 feet of work was done in the two years' operation at this shaft. It was discontinued in December [1917].

At shaft No. 128, also on the east shore of Cobalt lake and some distance north of shaft No. 81, development work was done in a basin of conglomerate,

around the edges of which a number of veins were opened up on the surface. At the 120-ft. level of the shaft, 685 feet of crosscutting was done in various directions, but no ore was discovered.¹

At shaft No. 150, on the east side of Cart lake, much prospecting was done in the Cobalt series. From the 209-ft. and 309-ft. levels, crosscuts were run in various directions, and several calcite veins were found and developed, but no ore was discovered in them.² The work proved that the Cobalt series had a thickness of about 300 feet. Operations were discontinued in the year 1915.

Shaft No. 86, at the west side of Cart lake, was inaccessible in 1921 and the writer has no information concerning the workings connected therewith.

Shaft No. 19, on Nipissing hill, was reopened in 1921 to extract the ore remaining in No. 6 open cut which had not been worked since the early days of the property. Vein No. 130 will also be mined through this shaft.³ The group of veins (Nos. 6, 7, 129, 130, and 131) around shaft No. 19 has produced important quantities of silver from the Keewatin. The total silver yield from these veins did not, however, amount to as much as the output from vein No. 26, which was the largest producer from the Keewatin. Veins Nos. 12 and 40 yielded some silver from the Keewatin

Nipissing Mine Workings from Shaft No. 63

South of the south end of Cobalt lake, there is a valley or depression in the Keewatin which is now partly filled with sediments of the Cobalt series. This valley strikes southward, but towards the south end it broadens out and the east side of the valley strikes southeastward, as shown on the plan of the second level from No. 63 shaft. Cutting across this ancient valley, more or less at right angles to the strike of the valley, there are several veins, of which No. 63 (Kendall), the "Little Silver," and No. 251 are examples. Most of the veins extend up to, or into, the Keewatin on the west side of the valley, but only a few have been traced eastward to, or into, the Keewatin on the east side of the valley. The veins strike about eastward on the north part of the valley, but towards the south they strike more northeastward.

There is a reverse fault at the east side of the valley. The fault strikes about south-southeast and dips eastward 55° to 65° . The west side of the fault is the downthrow side, but the amount of the displacement is not known. The fault appears to be exposed on the surface near the narrows between Cart and Peterson lakes. It may be a branch of the Cobalt lake fault, although the two faults have not been connected by mine workings.

The veins occurring in this valley are worked almost entirely from shaft No. 63. The workings from this shaft, the second most important one in the Nipissing property, may now be briefly described, beginning with the bottom level.

Third Level.—(Elevation above sea-level 779 feet.) The level was flooded and inaccessible at the time of our examination in 1921. The workings, and the reported location of the veins, are shown on the plan.

Second Level.—(Elevation above sea-level 854 feet at No. 63 shaft.) This is the most extensive level from No. 63 shaft, the workings extending about half a mile in a north and south direction.

At the north end of the workings is the Kendall vein. It is about vertical where it occurs in the Cobalt series, but where it occurs in the Keewatin it dips south-

¹Annual Report of the Nipissing Mines Company, Limited, for the years 1918 and 1919.

²Annual Report of the Nipissing Mines Company, Limited, for the years 1912, 1913, 1914' and 1915.

³Annual Report Nipissing Mines Company, Limited, for the years 1921 and 1922.

ward about 58°. The vein follows, for part of its course at least, a minor fault. This fault contains a gouge and breccia as wide as five inches in places. At the east end the vein leaves the fault; where it leaves the fault, the vein becomes smaller and finally almost pinches out in 100 feet. The vein enters the Keewatin about 20 feet east of the shaft, and it was followed by a drift for about 190 feet west of the shaft. It was not productive in the Keewatin, although it is six inches wide in places, consisting of calcite and some aplite.

Vein No. 108 crosses the Kendall vein about at right angles. This vein also follows a minor fault, which contains varying amounts of gouge and fault breccia up to four inches wide at one spot, but in most places less than this.

Vein No. 148 is stoped, although the stope is very narrow.

Extending southeast from vein No. 148, there is a minor fault consisting of less than an inch of gouge and fault breccia. Here and there in it there is a little calcite. The fault is open for an inch or two; whether these open parts are due to a leaching out of the vein matter, or whether the fissure was never filled in these places, was not determined.

The next vein to the south is known as the "Little Silver" vein. On this level it splits at the west end and these two branches apparently pinch out as they enter the Keewatin. The east end of the "Little Silver" pinches out gradually until finally it is a joint crack with about an eighth of an inch of calcite in it. As the plan shows, the vein pinches out about 200 feet west of the Keewatin on the east side of the Keewatin valley.

About 150 feet south of the "Little Silver" vein, there is a vein-system of minor importance, Nos. 250 and 253.

Some 300 feet south of the last-mentioned veins there is another important group of veins, namely, Nos. 251, 254, 256, 259. In vein No. 251 (259), there was discovered in the summer of 1921 an important shoot of high-grade ore about 70 feet long and three inches wide, assaying 3,500 ounces of silver per ton. Since the writer examined this shoot in October, 1921, the level 55 feet below has been opened up and a shoot of ore in the vein disclosed having a length of 265 feet, a width of two inches, and an average assay of 2,900 ounces, according to the annual report of the company for the year 1922.

South of the last-mentioned group of veins there is another vein-system striking northeastward. The silver in these veins is reported to be erratically distributed and the production has not been large.

On the second level the basal conglomerate of the Cobalt series is, generally speaking, composed almost entirely of fragments of the underlying Keewatin. The contact between the Keewatin and the Cobalt series is therefore not sharply defined. It was, consequently, often difficult to decide as to where the contact should be shown on the plan. The contacts indicated on the plan should be regarded as approximate.

At the south end of the workings, the plan shows a bed of finely banded slatelike greywacké. The bed dips at angles of 10° southeastward, the steeper dips occurring near the southeast corner of the workings. It would appear that these steeper dips show that some folding has taken place in this area.

On the east side of the valley, opposite the "Little Silver" vein-system, a major fault was met with in two crosscuts. This fault is a reverse one, the Keewatin series having been thrust on top of the Cobalt series. The fault strikes south-southeast and dips eastward at 55° to 65°. There is a gouge one to two inches wide and a fault breccia of three or four feet, the Keewatin being more crushed than the conglomerate. An irregular vein of barren pink calcite and quartz occurs in the fault. This vein pinches and swells, and is an inch or

two wide. At the east side of the fault the Keewatin floor appeared at one place to be dipping about 20° westward.

First Level.—(Elevation above sea level 941 feet at No. 63 shaft.) The veins worked on this level include the Kendall, the "Little Silver," and Nos. 99, 102, and 109.

The Kendall has been stoped out on this level, except at the shaft where the vein was still intact in the year 1921, showing a width of four to five inches.

The "Little Silver" vein has a length of about 450 feet and has been stoped for about 200 feet. The stope averages about 15 feet in width, its widest portion being in the slate-like greywacké. At the east end the vein gradually pinches out, while at the west end it enters a fault in a gentle curve. When the vein enters the fault, it becomes barren of silver, as far as the writer could observe. The fault consists of an inch or two of fault breccia and gouge, together with some calcite which cements the rock fragments. The fault is almost vertical, dipping 80° northeastward. About 30 or 40 feet southeastward of the "Little Silver" vein, there is a parallel vein with a length of 250 feet. At the east end it also gradually pinches out, while at the west end it also gradually enters in a similar manner the fault just referred to.

The south end of the first level is not connected directly with the north end, but is reached through winze No. 102-13. The veins in this part of the level are Nos. 99, 102, 109, all producers.

The first level is characterized by the bed of slate-like greywacké, which in winze No. 102-13 is 35 or 40 feet thick. The bed dips eastward at angles of 7° to 25°, the steeper dips occurring at the south end.

It may be added that none of the workings on the first level extend far enough to the east to intersect the reverse fault which was found on the level below in two crosscuts.

Tunnel Level.—(Elevation above sea level 1,024 feet.) This level is reached from a tunnel, and it may also be reached from winze No. 102-13. There are two important veins on the level, namely, Nos. 96 and 109.

Vein No. 28 Tunnel

Vein No. 28 tunnel is one of the longest tunnels in the camp. It is about 150 feet south of shaft No. 81, and it extends southeastward for some 1,800 feet from the east shore of Cobalt lake. In 1921 the tunnel was accessible and we were able to examine it. The following notes concerning the tunnel may be of interest.

The Cobalt series, dipping northwestward at about 25°, occupies the tunnel, or adit, for about 120 feet southeastward from the mouth of the tunnel. In this part the vein is about an inch and a half in width and consists of smaltite and calcite. It occurs in a minor fault which contains less than an inch of fault breccia and gouge. On entering the Keewatin, in which series the remaining part of the tunnel was run, the vein pinches out, but the fault appears to extend southeastward almost to the end of the tunnel, although it leaves the tunnel in one place, only to appear again towards the southeast end. The fault, where it occurs in the Keewatin, is about vertical and contains one to two inches of fault breccia and gouge. It has, here and there, lenses of calcite and quartz, fractions of an inch in width, together with a little smaltite, cobalt bloom, and nickel bloom.

About 625 feet from the portal of the tunnel, there is a crosscut striking southwestward; in this crosscut, about 60 feet from the tunnel, there is a calcite vein three or four inches wide carrying galena, zinc blende, and copper pyrites. The next crosscut to the southwest has a vein of calcite in it several inches wide; the vein is in a minor fault.

MINING CORPORATION

The Mining Corporation of Canada, Limited, owns the Buffalo, City of Cobalt, Cobalt Lake, Townsite, and Townsite Extension properties at Cobalt, and also several properties in South Lorrain, chief of which are the Frontier and Crompton. The Buffalo was bought in the year 1919 and is operated under the name of the General Examining and Developing Company. The Mining Corporation leased Peterson and Cart lakes in the year 1922, and in 1919 leased the Foster mine.

The Frontier and Crompton mines are described in that part of the report dealing with South Lorrain.

In recent years the Mining Corporation has made an energetic search for properties of merit. The company's campaign has taken its mining engineers into the farthest corners of the earth. China, Russia, Nicaragua, Bolivia, Chile, Peru, Mexico, and the United States have been searched. The company finally succeeded in May, 1921, in acquiring a majority interest in the Flin Flon mine in northern Manitoba. The engineers report that there are in this mine 16,000,000 tons of assured ore averaging 1.82 per cent. of copper, together with 1.16 ounces of silver per ton and \$1.60 in gold per ton.

The Mining Corporation of Canada, Limited, has a capital of 1,660,050 fully paid shares of a par value of \$5.00 each. To the end of the year 1922 the company had produced 34,906,491 ounces of silver. The number of fine ounces of silver which each property produced is given in the following table.¹

PRODUCTION IN OUNCES BY MINING CORPORATION OF CANADA, LIMITED, FROM TOWNSITE, CITY, COBALT LAKE, AND BUFFALO MINES

	Townsite	City	Cobalt Lake	Total	Buffalo	Total
Prior to 1908.....	53,743	64,873	.....	118,616	.....	118,616
Year ended Dec. 31, 1908.....	94,926	538,590	.....	633,516	.....	633,516
" " " 1909.....	25,918	416,336	.....	442,254	.....	442,254
" " " 1910.....	200,707	271,258	.....	471,965	.....	471,965
" " " 1911.....	832,381	242,745	701,876	1,777,002	.....	1,777,002
" " " 1912.....	1,494,029	210,650	1,123,147	2,827,826	.....	2,827,826
" " " 1913.....	2,754,042	56,763	973,913	3,784,718	.....	3,784,718
Jan. 1, 1914 to Mar. 31, 1914.....	407,663	105,303	353,656	866,622	.....	866,622
April 1, 1914 to Dec. 31, 1914.....	1,621,449	691,024	872,651	3,185,124	.....	3,185,124
Year ended Dec 31, 1915.....	1,963,540	1,023,865	1,576,551	4,563,956	.....	4,563,956
" " " 1916.....	1,737,959	1,742,954	976,528	4,457,441	.....	4,457,441
" " " 1917.....	1,996,549	2,181,106	307,887	4,485,542	.....	4,485,542
" " " 1918.....	.....	.....	.....	1,708,252	.....	1,708,252
" " " 1919.....	.....	.....	.....	1,230,653	.....	1,230,653
" " " 1920.....	.....	.....	.....	1,664,018	.....	1,664,018
" " " 1921.....	.....	.....	.....	495,512	731,205	1,226,717
" " " 1922.....	.....	.....	.....	497,232	965,037	1,462,269
Total.....	.....	.....	.....	33,210,249	1,696,242	34,906,491

The cost of producing silver in 1922 was \$11.96 per ton, or 56.29 cents per ounce, based on a production of 23,404 tons which produced 497,232 ounces of silver. At the Buffalo the cost was \$7.39 per ton, or 46.32 cents an ounce, based on a production of 62,218 tons which produced 965,037 ounces of silver. The table below gives a summarized statement of costs.²

¹Ninth Annual Report of the Mining Corporation of Canada, Limited, for year 1922, p. 11.

²Ninth Annual Report of the Mining Corporation of Canada, Limited, for year 1922, p. 12.

SUMMARIZED COSTS, MINING CORPORATION, 1922

	Labour	Material	Other	Total	Per ton	Per oz.
						cents
Mining costs.....	\$54,975.83	\$19,779.36	\$8,561.45	\$83,316.64	\$3.56	16.76
Milling and reduction (mine ore).....			63,725.14	63,725.14	2.72	12.82
Milling and reduction (tailing).....			85,548.49	85,548.49	3.66	17.20
Freight and realization (in- cluding selling and smelting charges).....			27,456.60	27,456.60	1.17	5.52
Administration and general	8,868.65	2,508.35	8,450.12	19,827.12	.85	3.99
Total.....	\$63,844.48	\$22,287.71	\$193,741.80	\$279,873.99	\$11.96	56.29
General Examining and Developing Co., Ltd., Buffalo mine, total cost....	\$115,582.38	31,656.34	250,196.47	397,435.19	5.83	41.18
Total.....	\$179,426.86	\$53,944.05	\$443,938.27	\$677,309.18	\$7.39	46.32
Head office, royalties, taxes, etc.....			84,198.09	84,198.09	.92	5.76
	\$179,426.86	\$53,944.05	\$528,136.36	\$761,507.27	\$8.31	52.08

Ore Reserves

The ore reserves at the end of the year 1922 consisted of 19,585 tons of broken ore in the stopes, while the tonnage of possible ore in place was stated by the management to be problematical. In other words, the City of Cobalt, Buffalo, Townsite, Townsite Extension, and Cobalt Lake properties are so intensively prospected and mined that ore reserves are now at a low ebb. The favourable development, however, of the corporation's properties in South Lorrain has given the company much promising area to exploit.

Structure

The rocks at the Mining Corporation properties at Cobalt consist of the Cobalt series which rests unconformably on the Keewatin series. The Cobalt series has produced practically all the ore, although the east wall of the Cobalt lake fault vein, which yielded important quantities of silver ore, is Keewatin.

The thickness of the Cobalt series is variable. On the west it thins out and finally disappears. At the southeast corner of the Buffalo it has a maximum thickness of over 244 feet. On the east side of the Townsite it has a maximum thickness of over 385 feet, while at the northeast corner of the City of Cobalt it has a maximum thickness of over 346 feet. At the north end of Cobalt lake the series has a thickness of about 510 feet, as proved by a drill hole from the fifth level at the north end of the Townsite Extension; the location of this hole is shown on the plan of the fifth level of the Townsite Extension. At the base of the Cobalt series there is a conglomerate bed; this is followed by a bed of slate-like greywacké, then by conglomerate, then by a thicker bed of slate-like greywacké, and finally by conglomerate. The slate-like greywacké beds, which are called "slates" by the miners, are irregular and often pass gradually into conglomerate, so that it is difficult to map them. The beds are not continuous. The general outlines of the beds are, however, shown on the plans.

The Keewatin consists of basalt, interbedded with which are beds of "iron formation", consisting chiefly of finely banded chert together with slate, the beds resting almost in vertical attitude and striking a little south of east. They are cut by small dikes of felsite.

Lamprophyre dikes cut the Keewatin series. At the City of Cobalt shaft an intrusion of lamprophyre has by its presence obscured the position of the Keewatin "iron formation" which apparently extends eastward from the Buffalo mine.

The geological mapping of the Mining Corporation's properties was done almost entirely by Mr. James Hill, who was assisted by Mr. David Hill. The writer spent a few weeks going over their work, but the plans show the geology substantially as they mapped it. During the work the Ontario Department of Mines had the valued advice and criticism of Mr. Warren H. Emens of the Mining Corporation, who is more familiar with the geology of the company's properties than any other geologist.

Veins

As discussed elsewhere in the report, it may be again pointed out that many of the veins on the Townsite and the south end of the Buffalo, Cobalt Lake, and City of Cobalt properties occur above or near a depression or trough in the Keewatin series. This depression in the Keewatin may have been caused by erosion; or it may have been caused by folding after the Cobalt series was laid down. Possibly a combination of these two causes may have accounted for the depression. That is to say, there may have been an erosion valley in the Keewatin which was subsequently filled with sediments of the Cobalt series; folding, parallel to the axis of the valley, may have deepened the depression. Whatever is the cause of the depression, the fact remains that the veins referred to occur above or near this trough in the Keewatin.

The vein-system at the northeast corner of the City of Cobalt property is reported to have produced about 12,000,000 ounces of silver. The two most important veins in this corner are No. 24 and No. 32. The writer is indebted to Mr. W. F. Fancy, mine captain of the Mining Corporation, for the following interesting information regarding the discovery of this vein-system. In 1913 the quantity of known ore on the City of Cobalt property was small, and the company was diligently searching for new veins. At that time it was the custom of Mr. C. E. Watson, resident manager, and Mr. Fancy to spend certain afternoons together examining the old workings which had been operated by a former company. On the second level there was a long crosscut extending from the City shaft northward to the Coniagas boundary line. This crosscut had encountered no ore. One afternoon Mr. Watson and Mr. Fancy were examining the crosscut and Mr. Fancy noted a crack in the rock about ten feet south of the north end. He found a few specks of cobalt bloom in the crack. After a consultation as to the advisability of prospecting this crack, Mr. Watson instructed that a drill be started and that the crack be followed southeastward. The location of this crack is shown on the plan of the second level of the City of Cobalt property on Sheet No. 31a-12. The crack was accordingly followed about 35 feet, where it met with a four-inch vein of smaltite running about at right angles to the drift. The vein was immediately sampled, but the result was disappointing. It assayed but four ounces of silver to the ton. When, however, the next round of holes was blasted the vein was found to assay about 1,500 ounces of silver per ton. The finding of this vein was the means of discovering the vein-system known as No. 24-No. 32, which is reported to have yielded about 12,000,000 ounces of silver.

The old company, which had previously worked the property, had diamond-drilled this part of the mine. The drill barely touched vein No. 29 at a barren spot. Afterwards, when the Mining Corporation was stoping this vein, the diamond-drill hole was found in the stope. Truly, luck often plays a vital part in the fortunes of mining companies!

Many of the veins in the Mining Corporation properties have a strike a little south of east. This is about the strike of the Keewatin "iron formation", as shown on the level plans. It would appear that the strike of many of the veins was governed, to a certain extent at any rate, by the strike of the "iron formation."

One of the interesting features of the veins in the company's properties is the occurrence of ore in the Cobalt lake fault (Fig. 18). The writer was not able to obtain a record of the quantity of silver which the ore-shoots in the fault produced, but it is reported to have amounted to at least a few hundred thousand ounces.

Regarding the ore in the Cobalt lake fault, Mr. D'Arcy Weatherbe, consulting engineer of the company for several years, has the following remarks to make:—

The most important results attained during the year were these from exploration and development on the Cobalt lake fault. It follows the eastern boundary of the lake and has a pronounced dip to the eastward. During the past year [1915] a programme of very energetic development work was followed on this fault, consisting of three crosscuts from the old workings, each of which intersected the fault at lower levels than any on which it had previously been explored. From these intersections, three levels, the fourth, fifth and sixth, were driven for long distances northerly and southerly and several very rich ore-shoots were discovered and worked. The ore consists largely of argentiferous niccolite. In one stope the vein averaged about eleven inches in width, and at one point exceeded two feet.¹

The various properties of the Mining Corporation are described below. Reference to Sheet No. 31a-12 in the map case accompanying the report will make the descriptions more readily followed.

BUFFALO

Prior to its acquisition by the Mining Corporation of Canada, Limited, the Buffalo Mines, Limited, had a capital of \$1,000,000 in shares of a par value of \$1.00 each; in 1918 the capital stock was reduced to \$750,000. The Buffalo Mines before it was acquired by the Mining Corporation paid \$2,787,000 in dividends, the last one paid being on May 28th, 1914.

The following account of the Buffalo mine is, in part, summarized from the notes of Mr. James Hill, who in 1921 examined and geologically mapped the property for the Department.

Veins

There are two main vein-systems, one at the south end and one about the middle of the property. These veins for the most part strike a few degrees north of west and dip at approximately 80°. Midway between the systems there are two parallel veins which carry fair ore.

The system at the south end of the property includes Nos. 3, 10, and 12 veins together with connecting networks. There is a continuous stope along this system having a length of 960 feet, not including branch veins. The stope on No. 10 vein extends into the City of Cobalt property. The greater part of

¹Second Annual Report, Canadian Mining Corporation, for year ended March 31st, 1916. p. 32.

the stope is five to seven feet wide, but at the east end, at No. 12 shaft, there is a large open cut, which is some 75 feet in width. The grade of ore in this system varies from point to point.

The system in the middle of the property includes veins Nos. 5 and 6, together with connecting network. Vein No. 5 has a stope 400 feet long, not including branch veins, and it continues into the Nancy Helen. The stopes are from five to seven feet wide. An open cut has been worked in this system.

Vein No. 21 is of interest as it is the only vein in the property that was productive in the Keewatin. The vein is near No. 4 shaft, and is stoped up from the third level nearly to the second. About one-half the stoping height is in the Keewatin. The vein was cut off in the conglomerate by a gently dipping joint plane in which there is a calcite stringer about one-quarter of an inch wide.

Faults

There are two vertical faults, one known as the galena fault and the other as fault No. 6 (Fig. 8). The galena fault strikes a few degrees north of west and parallels the vein-system known as Nos. 3, 10, and 12 at the south end of the property. No. 6 fault occurs in the middle of the property and parallels the vein-system known as Nos. 5 and 6. It also strikes a little north of west. The galena fault, as its name implies, carries galena. On the second level there were in places four inches of pure galena in the fault. The fault contains gouge and fault breccia having a combined width of one-half an inch to twelve inches. On the third level for 100 feet along the east end of the fault, the rocks adjacent to the fault are much crushed. The fault may be seen cutting the slate-like greywacké in the east end of No. 10 stope; it does not displace the bed, and no displacement of the beds was anywhere noted. At the east end of the fourth level, the fault dips 75° to the north, while at the west end on the third level it dips 75° to the south, but in general it is about vertical. It is of interest to note that the galena fault dies out in the City of Cobalt property before it reaches the Cobalt lake fault.

Fault No. 6 has a fault breccia and gouge from one-half to eight inches wide, probably averaging from one-half to one inch. The workings of No. 5 open cut were inaccessible, and therefore it was not possible to see how far the fault extended to the east. Where it crosses the contact fault, described below, there is in one place a fault breccia of about four feet.

In addition to the vertical faults described above, there are gently dipping faults which, in a general way, parallel the contact between the Keewatin and Cobalt series. Chief of these faults is that known as the "contact" fault. On the plan of the first level of the Buffalo, the contact fault is shown commencing at the north shaft; it strikes southward, passing about 175 feet east of No. 6 shaft and about 120 feet east of No. 4 shaft. It extends northeasterly into the Coniagas and Trethewey properties. The contact fault appears to be a reverse one, but it has not been possible to determine definitely the amount of displacement, owing to the fact that the fault more or less parallels the bedding of the Cobalt series, and parallels the contact between the Keewatin and Cobalt series. The fault dips from the surface to the third level at No. 12 shaft at an angle of approximately 25°; below this it dips in places more gently at 12° to 15°, following for a distance a bed of slate-like greywacké. In certain parts the fault dips at angles as high as 27° to 45°. Between the third and fourth levels it passes into the City of Cobalt mine. The fault breccia and gouge average perhaps an inch or two in width; north of No. 12 shaft on the third level the rocks are crushed in the vicinity of the fault, which in this part splits.

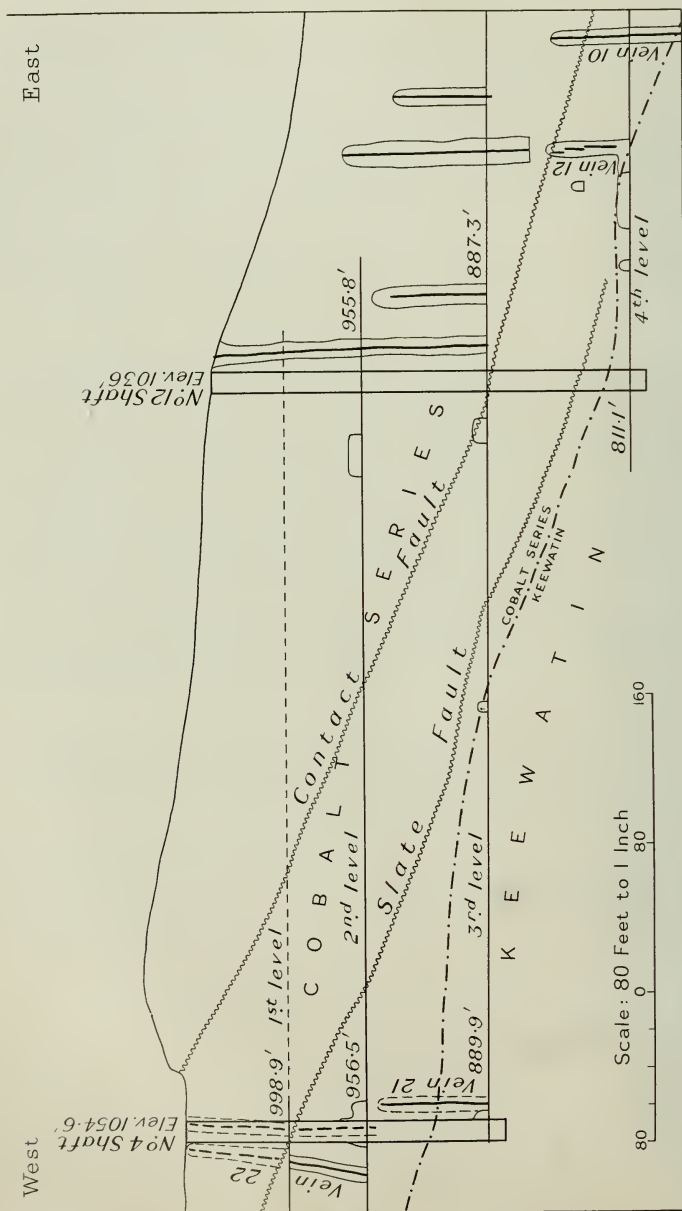


Fig. 17—Vertical section showing relation between the "contact" fault and veins, Buffalo mine.

Relation of Veins to Faults

The galena fault about parallels veins Nos. 3 and 10, and it appears to be older than these veins; the latter pass into the fault in places and do not appear to be disturbed by the fault. In the open cut in at least one place, the fault contained high-grade silver ore, some of the silver occurring in wire forms.

The age relation of the "contact" fault to the veins is puzzling.

Buffalo Mine Workings

There are five levels in the Buffalo mine, the lowest of which, the fifth, was not accessible at the time of examination in the latter part of the year 1921. The following notes regarding these levels may be put on record:—

Fifth Level.—(Elevation above sea level 785.9 feet.) The Mining Corporation furnished the Department with sufficient information to show the contact between the Cobalt series and the Keewatin series. The contact is shown striking east and west, parallel to which is a vein which splits at the west end. The vein and its branch are stoped.

Fourth Level.—(Elevation above sea level 811 feet at No. 12 shaft.) The Keewatin on this level consists of "iron formation" made up of finely-bedded chert and slate dipping about vertically, and impregnated with iron pyrites. The "iron formation" is cut by lamprophyre. The contact between the conglomerate of the Cobalt series and the Keewatin "iron formation" is sharp, although the surface of the Keewatin is jagged.

The feature of this level is the occurrence of a fault, which has been called by the miners the galena fault on account of the fact that it carries in places a galena vein a few inches wide. It also contains zinc blende and iron pyrites. The fault is in the same drift in which No. 10 vein occurs.

The fault consists, for the most part, of a gouge and breccia up to about a foot in width. In places there is in the fault a vein of smaltite and calcite carrying native silver. This vein may still be seen at the east end of the level, where it consists of about half an inch or more of smaltite and calcite with a clay gouge about half an inch wide on the north side and a fault breccia about ten inches wide on the south side. The vein is not disturbed or brecciated. At this point a parallel vein of smaltite occurs a few inches north of the fault, but this parallel vein is frozen to the country rock. At this end of the drift, No. 10 vein is a few feet north of the galena fault; in other places it is in the fault.

No. 10 vein at the west end of the level practically pinches out in the vertical beds of Keewatin chert or slate. The galena fault also appears to have pinched out when it reaches these chert and slate beds.

Third Level.—(Elevation above sea level 887 feet at No. 12 shaft.) The Keewatin series on this level contains the bed of "iron formation" consisting of chert and slate some 300 feet in width. This bed was encountered on the fourth level. It strikes westward, and the beds are in about vertical position. This "iron formation" bed is well exposed in the long crosscut running south from No. 6 shaft. To the north of the "iron formation" there is a bed of basalt 375 feet thick; while at No. 6 shaft an intrusion of lamprophyre and a small area of chert-like rock occurs.

East of No. 4 shaft a small intrusion of felsite appears to cut the "iron formation."

The galena fault is weaker in the Keewatin than in the Cobalt series. In the latter it has in places a foot of fault breccia. Some horizontal scratches were noted in the walls of the fault, indicating horizontal movement.

The contact fault has about three or four inches of fault breccia and half an inch of gouge.

Second Level.—(Elevation above sea level 955 feet at No. 12 shaft.) The junction of the galena and contact fault is exposed in the back of the drift at the south end of the workings. The contact fault appears to have faulted the galena fault about 18 inches, that part of the galena fault which is on the east of the contact fault having been moved to the north.

The contact fault on this level contains in places a vein of calcite and quartz up to two inches wide.

Fault No. 6, running southeast from No. 6 shaft, contains an inch or two of fault breccia and gouge.

In the southwest corner of the level there is a network of veins connected with vein No. 3 and the galena fault. In this area a bed of slate-like greywacké, four or five feet thick, rests almost directly on the Keewatin floor.

First Level.—(Elevation above sea level, 998.9 feet at No. 4 shaft.) This is the most extensive level in the mine, extending as it does from the north to the south boundary. The contact fault is shown to extend from the north to the south end of the level. At the south end it dips as steeply as 45° to the east; in places the fault breccia at this end of the mine is as wide as two feet. The contact fault apparently splits at the south part of the level. At the south end of the level the contact fault is over 500 feet east of the contact between the Cobalt series and the Keewatin series, but, towards the north, the fault converges closer and closer to the Keewatin until finally at the north end the fault is at the contact.

Vein No. 6 passes from the Cobalt series into vertical beds of "iron formation", the strike and dip of which it appears to follow.

CITY OF COBALT

The records of the Mining Corporation show that the City of Cobalt produced 7,545,461 ounces of silver during the years 1908 to 1917 inclusive. After the year 1917 the records do not show the separate production from the Townsite, City and Lake properties.¹

As already stated in this report, the veins on the City of Cobalt consist of an isolated vein-system at the northeast corner of the property known as No. 24-No. 32 and of veins at the south end of the property, some of which are the eastward extensions of veins on the Buffalo and Townsite.

The interesting feature of the vein-system at the northeast corner of the City of Cobalt property is the extension of vein No. 32 through what has been called the "west" fault with little or no displacement. Regarding this occurrence, Mr. D'Arcy Weatherbe remarks:—

The most interesting development at the end of the year 1917 consisted in the work on vein No. 32, which has, somewhat unexpectedly, been followed *through* the west fault, with apparently little or no displacement and was producing excellent high-grade ore.²

Mr. Weatherbe has described the vein-system at the northeast corner of the property in the annual report of the company for the year 1915, and his description is quoted below:—

Vein No. 24 when first found, had a strike northwesterly and southeasterly but later on turned to the east, and a winze sunk from the 200-foot level intersected the Keewatin formation at about the 300-foot level. This winze proved the ore-shoot to be over 70 feet high at that point. On the 300-foot level the vein was followed for some 280 feet east of the winze. The

¹Ninth Annual Report of the Mining Corporation of Canada, Limited, for year 1922, p. 11.

²Fourth Annual Report of the Mining Corporation of Canada, Limited, for year 1915, p. 11.

ore was replaced by calcite but the Keewatin contact is dipping in that direction, and indications point to a probable continuance of the shoot on its pitch to the east below the 300-foot level. Northwest of the winze vein No. 24 is supplying some exceedingly rich ore, and another strong high-grade vein, similar in character to vein No. 24, and parallel to that portion of it northwest of the winze, has proved to extend northwesterly from the winze for about 130 feet. This vein is numbered 27. Meanwhile development to the west and southwest of the winze has proved an ore-shoot on a third rich vein, or system of parallel veins (No. 29), which also follows the Keewatin formation on its pitch similarly to 24 and 27. This ore-shoot, which approximates No. 24 in height, had been followed to the southwest of the winze for some 285 feet by the end of the year, and showed every indication of further extension in that direction. A somewhat obscure system of horizontal faulting intersects the whole rock containing these vein-systems and at places makes it difficult to follow the ore in the drifts. In the stopes, however, where the full widths of the ore bodies may more easily be exploited, the faulting appears to have had the effect of extending the silver deposition into the wall rock to such an extent that the stopes are occasionally carried to widths of 20 feet in pay ground. Development of branch veins and veinlets also tends to produce much larger quantities of ore than are at first apparent and in several cases indicate the possible existence of distinct high-grade ore bodies. The aggregate width of the high-grade ore from end to end of this vein system so far as exposed on veins 24 east of the winze and 29 west of the winze, will probably exceed 2½ inches and average in value over 2,000 ounces per ton.

The principal fault on the City of Cobalt property is known as the west fault. The location of the west fault is shown on the plans of the levels. If the west fault is the southward extension of the valley fault on the Nipissing, then it is a reverse fault with a displacement of some 75 feet. It has not, however, been proved that the two faults are one and the same.

The contact fault also occurs in the City of Cobalt property where it has been named the "reverse" fault on the plans.

It will be convenient in describing the workings of the City of Cobalt property to divide the property into two parts, namely, the south end and the north end. The south end includes the eastward extensions of the vein-systems on the Buffalo and Townsite. The north end deals with a distinct and important vein-system which has no connection whatever with the southerly system and is distant from it more than a quarter of a mile. The system at the north end has produced about twelve million ounces of silver.

South End of City of Cobalt

Fifth Level.—(Elevation above sea level 633.3 feet at City shaft.) This level is an important one from a mining point of view, since the electric haulage running from the south to the north end of the property is located here.

There are five parallel veins at the south end of the fifth level having the unusual strike of almost north and south—a few degrees east of north. The most westerly area is stoped out, and has at the south end a concrete dam which holds water up to the level above—the fourth. The stopes on this level, as far as we could see, are all narrow, some five to ten feet in width for the most part. Vein No. 31 is on the Townsite Extension.

The crosscut running east from No. 7 shaft on the Townsite is in Keewatin basalt. Conglomerate of the Cobalt series rests on the basalt, followed by a thick bed of slate dipping about 12° to 14° eastward.

The long drift and crosscut running north to the City of Cobalt shaft was unfortunately inaccessible, having been dammed. The location of the contact between the Keewatin and Cobalt series was obtained from Mr. Warren H. Emens of the Mining Corporation.

There appears to be a distinct valley in the Keewatin. The five veins referred to strike northward across this valley. A winze has been sunk on No. 31 vein, but it was flooded at the time of our examination.

There is a sub-level between the fourth and fifth levels.

Fourth Level.—(Elevation above sea level 701.7 feet at City shaft.) This level consists mainly of a north and south crosscut and drift paralleling the west boundary of the City of Cobalt. The main vein, No. 14, strikes a few degrees east of north. The stope is full of water, being held in by a concrete dam at the south part, referred to in the description of the level below.

The crosscut running north and south from the City of Cobalt shaft is partly in Keewatin "iron formation", but the "iron formation" is obscured by the presence of a lamprophyre dike which is somewhat schistose in places. The north end of the crosscut is basalt. In the crosscut running northwestward, opposite the City of Cobalt shaft, there is a rock containing fragments which consist largely of very fine-grained, greenish-grey material. There is, however, one rounded fragment of pink syenite about an inch and a half in width. The matrix of this fragmental-like material appears to be a lamprophyre. Certainly the south wall of the crosscut is lamprophyre.

The south part of the level was inaccessible at the time of our examination in 1921.

There is a ladderway, about 200 feet from the south end of the workings, by means of which it is possible to reach the sub-level below the fourth, and also to reach the fifth level.

Third Level.—(Elevation above sea level 758.3 feet at City shaft.) The galena fault on this level occurs about 40 feet south of the City of Cobalt shaft and it has been followed for about 200 feet eastward in a drift. No ore occurs in it, but in places there is a calcite vein less than an inch in width. The fault shows an inch or two of fault breccia and gouge. This drift appears to be in lamprophyre

What appears to be the contact fault may be seen in six places, the most northerly of which is at the City of Cobalt shaft at the station, where it is a weak structure and somewhat irregular, showing only an inch of fault breccia and gouge. Possibly its weakness is due to the fact that it occurs in the Keewatin at this point. Elsewhere on the level the fault shows from three to six inches or more of gouge and fault breccia. The fault strikes southwest and dips at 25° to 40° eastward.

The bed of slate-like greywacke on the level is resting in places, at unusually flat angles, dipping at as low angles as 7° to 8° eastward, but it also dips at angles as high as 15° to 20°.

The depression in the Keewatin on the third levels of the City of Cobalt and Townsite properties is well shown on the plans of the levels.

Second Level.—(Elevation above sea level 813.9 feet at the City shaft.) The second level is of interest on account of the fact that the vein-system known as No. 24-No. 32 was discovered on this level. The story of its discovery is given on page 65.

The galena fault extends about 100 feet east of the Buffalo. It appears to pinch out at the east end of the drift. The fault contains from an inch to two inches of fault breccia and gouge, although in places it is wider.

No. 10 vein of the Buffalo was, at the time of our examination, still to be seen in the party-wall between the Buffalo and the City of Cobalt; it is two or three inches wide. The vein is at the north side of the drift while the galena fault is at the south side, so that here the vein is not in the fault. In the stope, No. 10 vein made several jogs at horizons where it encountered well-defined joint planes in a bed of slate-like greywacké. This "jogging" of veins in the slate-like greywacké beds is of common occurrence at Cobalt (Fig. 25).

The contact fault, labelled "reverse" fault on the plan, has been followed 200 feet in a drift which about parallels the boundary between the City of Cobalt and the Townsite. The fault shows in places one-half to three-quarters of an inch of gouge and about 5 or 6 inches of fault breccia. In places the fault has a vein in it of the usual type characteristic of many fault veins, that is, of pink calcite and white quartz. This vein is up to 5 inches wide. The fault is well defined in this part of the workings. The contact fault is also well exposed on this level in a stope which is 100 feet east of No. 1 shaft on the Townsite. This is an important locality because it demonstrates that the fault is a reverse one. The reverse character is shown by the fact that the slate beds below the fault have been bent up.

Lamprophyre occurs at the City of Cobalt shaft. It also occurs at this shaft on the third and fourth levels.

First Level.—(Elevation above sea level 873.6 feet at city shaft.) The galena fault has been followed on this level for some 300 feet east of the Buffalo boundary line. At the east end it encounters a fault dipping about 35° to the southeast. The galena fault does not appear to extend east of this fault.

At the southeast side of the workings there is a bed of black and green slate dipping 12° to 15° to the southeast.

65-ft. Level.—(Elevation above sea level 945.6 feet.) This is not an extensive level. Only one vein has been stoped, and this is an eastward extension of vein No. 10 on the Buffalo. There are a number of small veins of pink calcite in the crosscuts, but these have not been drifted on.

About 100 feet north of the shaft there is a fault dipping 35° to the south. It has been met with in the workings from point to point for 300 feet; it strikes northeastward, and shows 2 to 4 inches of gouge and breccia.

The crosscut running over 200 feet south of the shaft was not accessible. The entire level appears to be conglomerate of the Cobalt series.

North End of City of Cobalt

Fifth Level.—(Elevation above sea level 652 feet at winze No. 10, vein No. 32.) The north end of the level is reached by a long crosscut from shaft No. 7 on the Townsite. This crosscut, which roughly parallels the Keewatin contact, follows the right of way of the Temiskaming and Northern Ontario Railway; the right of way is known as the Townsite Extension. This crosscut intersects a well-defined fault named on the map the "west" fault; the fault has several inches of fault breccia and, in places, as much as an inch of gouge. It has not been proved that the "west" fault is the southward extension of the "valley" fault on the Nipissing.

The writer has been unable to obtain much first-hand information concerning the important vein-system at the northeast corner of the City of Cobalt property. The veins were about worked out at the time of our examination. The stope on vein No 32 is, in places, about 6 feet wide.

Where vein No. 32 extends west to the Keewatin, there is a fault at the contact of the Keewatin and Cobalt series.

Vein No. 24 extends westward into the Keewatin where it then follows a fault dipping about 65° southward. The fault contains one to five inches of fault breccia and a quarter of an inch or half an inch of gouge, but there is very little vein material in the fault.

The Department is indebted to Mr. Warren H. Emens for the following information regarding the drill hole at the north end of the level. The hole dips at 30° and parallels the right-of-way of the railway; it is 411 feet deep.

The Cobalt series occurs at a depth of 400 feet, beyond which Keewatin was encountered for 11 feet. The elevation of the top of the hole is approximately 661 feet above sea level.

Sub-level between Third and Fifth Levels.—This level is at varying elevations. It may really be referred to as the fourth level. A little of the Keewatin "iron formation" was noted. The plan shows the location of the veins and faults.

Third Level.—(Elevation above sea level 738.7 feet at winze No. 24.) This level is reached from the second level by way of winze No. 24. A bed of Keewatin "iron formation" occurs on this level, and the same bed was encountered on the two sub-levels below and on the fifth level. It consists of chert and slate finely banded.

Vein No. 24 pinches out at a minor fault, which contains about an inch of fault breccia. On this level the vein did not extend as far east as the "west" fault. The stope is 6 to 8 feet wide, but in places as wide as 10 to 20 feet.

Vein No. 32 extended through the "west" fault, and the vein has been stoped above and below the fault. The latter has a fault breccia of 3 to 12 inches wide, and a gouge from one-eighth to one-quarter of an inch wide.

Sub-level above Third Level.—(Elevation above sea level 761 feet.) The "iron formation" strikes southward, and it was found that vein No. 29 followed its strike and dip. The usual strike of the "iron formation" in the area west of Cobalt lake is a little north of west. Its southwestward strike on this level is unusual.

The west fault dips at an angle of 55° , which is much steeper than the dip on the fifth level. The vein went through the fault and was stoped above and below the fault.

Second Level.—(Elevation above sea level 813.9 feet at City shaft.) This is the level on which the important vein-system No 24-No. 32 was discovered. An account of how it was found is given on page 65 of the report. The west fault was intersected in two crosscuts. It dips at 40° to 50° eastward. In the long crosscut at the south end of the workings, a fault resembling the west fault was not found, but there are a number of eastward dipping faults at about the place in which the west fault should be, if its normal strike continues southward. Possibly these minor faults represent the west fault. In other words, the west fault may have split up into several branches at the point where the crosscut intersects it.

First Level.—This is really a sub-level about 70 feet above the second level. It is of no importance.

COBALT LAKE

The lower workings in the Cobalt Lake property are the deepest of any of the properties owned by the Mining Corporation at Cobalt. Most of the levels were, unfortunately, filled with water in the year 1921, the property not being worked at that time.

The returns to the Government show that Cobalt Lake produced 6,899,933 ounces of silver.

Cobalt lake was pumped out in 1915. The dewatering was commenced on April 19th, 1915, and was completed on June 5th. Two centrifugal pumps and motors of 3,500 gallons per minute each were installed on a pontoon in the deepest part of Cobalt lake. The water was discharged through a 20-inch wire-wound, wood-stave pipe line, 3,600 feet in length,¹ to Farr creek.

¹Second Annual Report, Canadian Mining Corporation, for year ended March 31st, 1916, pp 27-28.

The principal veins consist of the vein in the Cobalt lake fault and veins No. 5 and No. 2. The two latter veins strike about eastward, but do not extend as far east as the Cobalt lake fault.

The vein in the Cobalt lake fault is of unusual width in places. On the second level from No. 4 shaft, it has a width of 4 feet in one place; in the stope above this level the vein has 15 inches of niccolite.

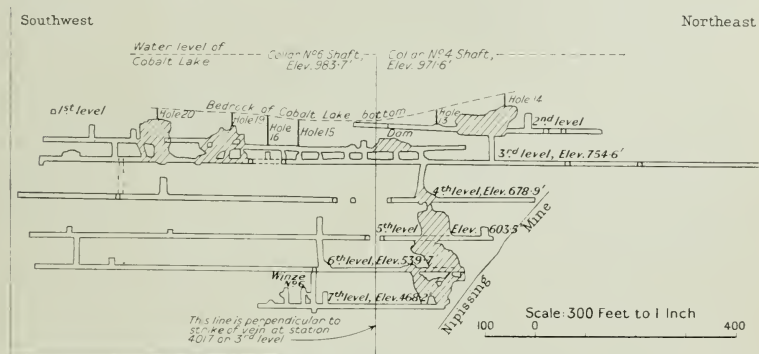


Fig. 18—Stope section in Cobalt lake fault vein, in Cobalt lake property (Mining Corporation).
Furnished by the Mining Corporation of Canada, Limited.

Fig. 18 shows a stope-section of the vein in this fault. An idea of the richness of the ore may be obtained from the record of sampling which is shown in the table below. This information was kindly furnished by the Mining Corporation.

Much work has been done on the fault, and it has been found that over long distances the fault is lacking in vein matter. On the third level the fault has been drifted on for nearly half a mile.

WIDTH AND GRADE OF VEINS, COBALT LAKE FAULT

SIXTH LEVEL						FIFTH LEVEL		
Sample	Width	Assay	Sample	Width	Assay	Sample	Width	Assay
	inches	ounces		inches	ounces		inches	ounces
1	3 1/4	59.4	20	19	23.8	1	3 1/2	178.4
2	7	86.8	21	8 1/2	28.2	2	5 1/2	846.1
3	4	68.4	22	7	22.4	3	10 1/2	262.4
4	3 1/2	122.8	23	8 1/2	14.2	4	13	607.5
5	5	67.6	24	9	23.6	5	13 1/2	863.3
6	12	51.7	25	7 1/2	88.4	6	17 1/2	1448.6
7	13	44.0	26	11	4453.8	7	18	1933.2
8	14	970.0	27	14	85.3	8	17	2990.0
9	9	0.5	28	6	1500.5	9	10 1/2	2078.6
10	9 1/2	0.5	29	9	455.0	10	11	2034.2
11	8 1/2	28.2	30	9 1/2	1198.6	11	9	976.8
12	7	0.5	31	8	601.4	12	7	1039.6
13	4	0.5	32	14	246.0	13	7 1/2	1290.5
14	5	0.5	33	17 1/2	537.8	14	13	749.6
15	6	0.5	34	16	1401.3	15	14	947.0
16	7 1/2	0.5	35	6	1400.2	16	15	1249.8
17	4	0.5	36	5	305.6	17	14	515.8
18	5	8.4	37	3	162.4	18	12	80.9
19	8	18.5	38	12 1/2	1789.9	19	8	264.4
						20	5	87.8
						21	5	60.0

Cobalt Lake Mine Workings

The fifth, sixth, seventh, and eighth levels were not pumped out in the year 1921. Hence no examination was made. The geology of the sixth level was, however, kindly furnished by the Mining Corporation. The extensive exploration work on this level represents a systematic and comprehensive piece of development. On the fifth level the contact between the Keewatin and Cobalt series is shown by a dotted line, this information having been furnished by the mining company.

Fourth Level.—(Elevation above sea level 678.9 feet at No. 5 winze.) The principal vein on the fourth level is No. 5. It is stoped out, and the stope is 5 to 12 feet wide and averages 10 feet wide in places. This vein-system pinches out before it reaches the Cobalt lake fault.

A well-defined fault, showing about 12 inches of fault breccia and gouge, occurs near the west end of No. 5 vein. The fault dips 26° eastward and is called the reverse fault. It is at the contact between a bed of slate-like greywacké and conglomerate.

The Cobalt lake fault has been drifted on for about 1,100 feet. In one place a crosscut was run through the fault at right angles to its strike. In this crosscut there is a fault breccia at least 15 feet wide, and the Keewatin is still crushed on the east face of the crosscut. The gouge is one inch wide. The rock in the fault breccia is schistose in places and the Keewatin is more crushed than the Cobalt series. On the west face of the gouge there is a vein of calcite 12 inches wide containing cobalt bloom. West of the vein there are 4 inches of rock, and west of the rock another vein consisting of 12 inches of pink and white calcite.

The Cobalt lake fault contains disseminated grains of cobalt bloom almost continuously along its entire stretch on this level; the width of the cobalt bloom is an inch or two, but in places it is 5 or 6 inches wide. The bloom occurs in or near the gouge. At the north end of the drift on the fault there is a vein of pure smaltite 3½ inches wide in places. This vein is exactly in the Cobalt lake fault; that is to say, it abuts against the gouge of the fault. Incidentally it may be remarked that no vein can be said to occur more exactly in the fault than one which rests against the gouge. It is along the gouge that the movement took place. In places the fault contains a calcite vein a foot or two wide; a little quartz occurs with the calcite.

Near the south end of the drift along the Cobalt lake fault, the fault splits; the east branch has been followed for about 50 feet, and it has a fault breccia 2 feet wide and a gouge about one-quarter of an inch wide.

Third Level.—(Elevation above sea level 754.6 feet at No. 5 winze.) The third levels of the Cobalt lake, Townsite, and City of Cobalt properties show particularly well the depression in the Keewatin series; and these levels also show how most of the veins occur in the Cobalt series above this depression. At the east side of the Townsite the depression is about 800 feet wide and about 125 feet deep.

The relation of the fault, called reverse fault on the plan, to the main vein may be seen in the stope. The vein has the appearance of being faulted 20 feet to the north by the reverse fault; that is to say, the part of the vein above the fault appears to have been moved 20 feet north. While the vein has the appearance of being faulted, there is a possibility that the vein came up to the fault and emerged above the fault 20 feet to the north; this possibility would simply mean that the vein is younger than the fault.

At the southwest end of the level, the Keewatin "iron formation" occurs. It consists of beds of chert and slate dipping steeply to the south. As shown on the plan, the bed of slate-like greywacké rests for some distance directly on the Kéewatin "iron formation", there being no conglomerate between the greywacké and the "iron formation."

The Cobalt lake fault has been drifted on for nearly half a mile, and at the south end has a calcite vein in it as wide as 18 inches. In places smaltite and niccolite occur in the fault. North of No. 4 shaft a little cobalt bloom occurs in the gouge.

The gouge of the Cobalt lake fault is in places 4 or 5 inches wide; this is a most unusual width.

About 60 feet northeast of No. 4 shaft the Cobalt lake fault splits; the east branch has been followed a short distance and shows several inches of fault breccia, but little or no gouge. There is a calcite vein in the east branch from one-half to an inch and a half wide. This vein, which is called No. 3, splits into small stringers which barely come up to the Cobalt lake fault. A raise follows the vein up to the first level where the vein was productive in the Cobalt series.

Second Level.—The second level is reached from No. 4 shaft on the east side of Cobalt lake.

The southwest part of the level is reached by way of No. 1 winze from the first level from No. 6 shaft at the south end of Cobalt lake.

The workings from No. 4 shaft are of particular interest on account of the fact that it is one of the best places to show that a vein occurs in the Cobalt lake fault. This vein pinches and swells, and in most of the fault there is little or no vein material. One of the lenses is of extraordinary width, namely, 4 feet at the widest place; this lens is about 65 feet long and consists mostly of calcite, but shows in places 9 inches of pure niccolite. The characteristic feature of the lens is that it is banded.

Along the entire length of the drift the Cobalt lake fault has an almost continuous streak of cobalt bloom in or near the gouge.

In the back of a stope above the level, there is a vein of almost pure niccolite 15 inches wide in the Cobalt lake fault. A diamond-drill hole was drilled vertically upwards at this point, and it was found that there were 20 feet of rock between the back of the stope and the bottom of the lake.

The writer has not had an opportunity to examine all of the stopes in the Cobalt lake fault, but those he has examined show that the ore is in the fault.

No. 3 vein, which is a branch of the Cobalt lake fault, has 15 inches of calcite in one place. The calcite goes directly into the Cobalt lake fault.

That part of the second level at the south end of the property, which is reached by way of No. 1 winze from No. 6 shaft, is not of importance. The veins and kinds of rock are shown on the plan.

First Level, No. 6 Shaft.—The level consists of a crosscut following the boundary of the property. The crosscut intersects the Cobalt lake fault, which here shows a less disturbed character than is usual.

First Level, No. 4 Shaft.—No. 3 vein on this level has been stoped, and in one place in the back of the stope the vein contains 8 to 10 inches of smaltite. The vein occurs in a fault which appears to be a normal one, the south side having dropped down, judging from the attitude of a bed of slate-like greywacké. That is to say, the beds on the footwall are bent downwards.

Townsite Extension

The Townsite Extension property consists of a long strip of land following the right of way of the Temiskaming and Northern Ontario Railway on the west side of Cobalt lake. The workings are described incidentally when dealing with the City of Cobalt, Townsite, and Cobalt lake properties.

Townsite

The Townsite property produced 13,182,906 ounces of silver during the years 1908 to 1917, inclusive. After the year 1917, the records of the Mining Corporation do not show the number of ounces of silver which this property yielded.¹

The following description of the Townsite is taken substantially from the notes of Mr. James Hill, who examined and mapped the mine for the Ontario Department of Mines.

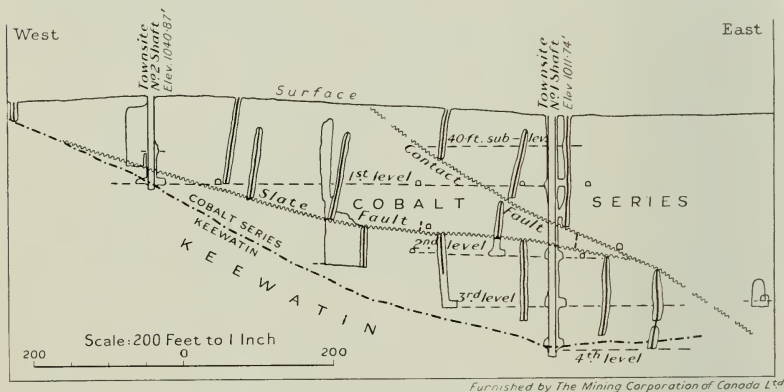


Fig. 19—Vertical section through No. 1 and No. 2 shafts, Townsite mine, showing relation of veins to "contact" fault and "slate" fault.

The Townsite property may be divided into two parts, namely, that operated from No. 1 shaft at the northeast corner of the property, and that operated from No. 4 shaft at the southwest part of the property. The levels from these two shafts are not at the same elevation. There are four levels connected with No. 1 shaft; there is also a fifth level from No. 7 shaft, but this fifth level consists merely of a short crosscut eastward to the City of Cobalt property. No. 4 shaft has two levels connected with it.

There are three faults in the property which are of importance. The first of these is known as the contact fault; this fault has been named on the plans the "reverse" fault. It is the southward extension of the contact fault on the Buffalo, and it dips eastward at angles of 25° to 40°.

Below this fault is one which follows the principal bed of slate-like greywacké; this fault has been called the slate fault, or slate slip, by the miners, and it dips southeastward at gentle angles. The contact fault and the slate fault are shown on the vertical section (Fig. 19). Both are reverse faults.

¹Ninth Annual Report of Mining Corporation of Canada, Limited, for year 1922, p. 11.

Near the south end of the property there is a normal fault known as X fault with a displacement of about 21 feet. It dips to the southward at about 75°, the south side being the downthrow side. This fault is probably the eastward extension of the Clear lake fault. It follows a vertical bed of Keewatin "iron formation" from Clear lake eastward to the Townsite. The fault contains a vein of good ore; in places the vein is several feet from the fault.

Workings from No. 1 Shaft, Townsite

First Level.—(Elevation above sea level 917.8 feet at No. 1 shaft.) Vein A is 240 feet long and extends to the surface. It is cut off below by the contact fault, and is stoped to a width of 5 to 10 feet. The ore is reported to have been very rich.

Vein Q is 265 feet long, and is cut off between the first and second levels by the slate fault which follows a bed of slate-like greywacké. The stope has a width of 5 to 7 feet. It pinches out before reaching the surface. The ore was very rich.

Vein L west is 300 feet long. About 55 feet of this vein at the west end extends down to the first level. From No. 3 raise westward, the base of the vein rises with the Keewatin floor, and the ore rises to the surface. The width of the stope is about six feet, and the ore was rich. There is a net work of veins, connected with vein L west, which is cut off by the Keewatin floor or by the slate fault.

P vein is 210 feet long. It is cut off at the northeast end by the contact fault on this level, but it follows down below the fault. At its southwest end it pinches out. The vein is cut off below the second level by the slate fault. The stope is 5 to 6 feet wide, and the ore is reported to have been rich.

Second Level.—(Elevation above sea level 820.2 feet at No. 1 shaft.) Veins P and P west have a combined stope about 360 feet long and a width of 6 feet. Vein P west is cut off at the floor of the second level by the slate fault. The ore was high-grade.

The stope in Q and L veins combined has a length of 310 feet and a width of 5 to 6 feet. Q vein is stoped up to the slate fault; the south half of vein L is deflected at the fault, but it is still in the stope, and is stoped nearly to the surface. The remainder of L vein was cut off above by the slate fault; the vein is cut off below by the Keewatin floor. Vein Q is cut off 20 feet below the second level at the base of the lowest bed of slate-like greywacké. These veins afforded rich ore.

Veins S and S east have a combined stope 330 feet long and 5 to 6 feet wide. The top of this vein-system follows down the contact fault. Below it is stoped down to the slate fault.

Third Level.—(Elevation above sea level 756.8 feet at No. 1 shaft.) The stope in vein No. 14, vein S east, and vein S has a total length of about 480 feet. The stope has a width of 10 to 15 feet for a distance of 70 feet. This is the largest stope in the Townsite mine. Vein S was stoped up through the second level to the contact fault. Vein S east and No. 14 were cut off above by the slate fault. This vein-system pinches out at the fourth level near the Keewatin floor. Vein S had poor ore, S east had high-grade ore, and No. 14 vein had ore of fair grade.

The stope in vein R continues into the stope in vein G, and the two stopes together have a length of 290 feet. The average width of the stope is 5 to 6 feet. Part of the stope in vein R has a width of 10 feet for a distance of 30 feet. These

veins are cut off above the third level by the slate fault, and continue downwards to the fourth level near the Keewatin floor.

The stopes in vein P west and vein P north have a combined length of 400 feet, and are 5 to 6 feet wide. These veins are cut off above by the slate fault, and they pinch out below near the Keewatin. Vein P west had high-grade ore, but vein P north was poor on this level.

Fourth Level.—(Elevation above sea level 702.1 feet at No. 1 shaft.) Vein No. 14 has a stope 380 feet long and 5 to 7 feet wide. It pinches out near the Keewatin. The stopes in vein G and vein R have a combined length of 200 feet and width of 5 to 7 feet.

Vein S has been stoped for 200 feet and the stope has a width of about 5 feet. Vein S and the net work of veins connected therewith are small and low-grade, and yielded mill-rock.

Faults

The contact fault strikes about north and south and is the southward extension of the contact fault on the Buffalo. On the first level it occurs about 100 feet west of No. 1 shaft and at the station of No. 7 shaft. It dips eastward at 35° to 37° . On the second level it passes into the City of Cobalt property; on the plan of the level this fault is named the reverse fault. On this level it dips eastward 25° to 30° . The contact fault has in places a fault breccia 1 or 2 feet wide. There are barren calcite veins in the fault, but these are never crushed. In the vicinity of No. 7 shaft on the first level, the rock is much crushed near the fault. There is evidence in the City of Cobalt property to show that it is a reverse fault.

The slate fault has been so named because it follows a bed of slate-like greywacké. In the northwest corner of the first level, the slate fault occurs at the top of a bed of slate-like greywacké. It dips with the greywacké at about 15° to the southeast. There is very little fault breccia or gouge in the fault. The location of the fault is shown on the vertical section (Fig. 19). The displacement along the fault is not known.

In addition to the contact fault and slate fault there are a few other faults, more or less parallel to the Keewatin contact; these are of less importance.

There are a number of almost vertical faults, the chief of which is known as "X" fault; it is probably the eastward extension of the Clear lake fault, and it follows a bed of Keewatin "iron formation." At the time of the examination in the year 1921, the best place to study X fault was in a raise in the fault above the second level. On the plan of the second level it may be seen that X fault, here named X vein, is at the extreme south end of the level. The fault strikes about west 20° north and dips at 75° southward. The south side has dropped down about 21 feet. This displacement may be accurately measured on account of the presence of a bed of slate-like greywacké. The fault breccia is up to 15 inches wide. Some horizontal movement has taken place along the fault, as the bed of slate-like greywacké in the hanging-wall is about one foot thicker than it is in the footwall.

On the second level a drift was run along the fault to prospect a calcite vein which occurs in the fault. The vein was not productive in this level, but was in the level above.

Structure of the Rocks

In the Keewatin rocks there is a depression or trough which strikes south-eastward and is now filled with conglomerate, greywacké, and quartzite of the Cobalt series. The contour of the trough on the fourth level is, as the plan

shows, horseshoe in shape, and it opens out into the old basin underlying the present Cobalt lake. The dip along the bottom of the trough is 15° to 22° southeastward. The dips of the beds of the Cobalt series are, Mr. James Hill believes, controlled by the slopes of the Keewatin floor; that is to say, the beds dip inwards towards the centre of the trough. As the trough was partly filled with conglomerate before the deposition of the slate-like greywacké, the dip of the slate-like greywacké bed is a little flatter than the dip of the floor of the trough, the slate-like greywacké dipping at angles of 6° to 20° , and the bottom of the Keewatin trough at 15° to 22° southeastward. Possibly, folding after the Cobalt series was laid down may have deepened the trough.

There are two beds of slate-like greywacké. The lowest bed, where it has been intersected by the workings on the fourth level, occupies about a third of the mineral area, and in two places it rests directly on the Keewatin floor; on the third level it occupies a small crescent-shaped area, and rests in one place directly on the Keewatin floor. On the second level it is only a thin bed of poorly-bedded sediments where it feathers out.

The second and higher bed of slate-like greywacké is in places about 16 feet above the first, and there is a bed of conglomerate between the two. This second bed of slate-like greywacké is 50 feet thick in "Q" stope, the thickness diminishing towards the surface and becoming thicker towards the southeast. This second bed covers about one-half the mineral area on the third level; while on the second level it forms a broad belt about 250 to 300 feet wide. On the first level it has narrowed down to a belt about 45 feet wide which almost rests directly on the Keewatin. It may be seen feathering out in L stope above this level. The lower part of this second bed is finely-banded greywacké, very fine in grain; higher up in the bed the sediments passes into quartzitic material which, however, has been included with the slate-like greywacké for mapping purposes.

A boulder of iron pyrites, 6 inches wide by 12 inches long, was found in the conglomerate on the first level of the Townsite. The pyrite was perfectly fresh.

Workings from No. 4 Shaft, Townsite

There are two levels from this shaft; part of the geology on the lowest level is shown.

The most important vein is known as "X" vein; it occurs in a normal fault having a displacement of about 21 feet, and containing fault breccia from 1 to 12 inches wide. On the first level the vein has been stoped for 380 feet, and on the second level for 470 feet. The stope has a width of 6 or 7 feet; in places barren calcite may still be seen from 8 to 12 inches wide. At the west end the vein consisted of smaltite 1 foot wide. In places the ore was rich. The vein is sometimes in the fault and sometimes in the wall-rock some 5 feet or more from the fault.

To the south of vein "X" on the first level, there are a number of other veins, chief of which is No. 8 which is stoped in places nearly to the surface. No. 8 vein is in or adjacent to a fault which has a fault breccia from one-quarter to two inches wide. The other veins south of vein "X" have for the most part been stoped only 10 or 20 feet above the level. The vein known as "X-6" produced fair ore; the other veins yielded about 10-ounce mill-rock.

On the second level there is a fault at the northeast end of the long crosscut running northeast under the railway track. This fault dips at 25° eastward, has a fault breccia and gouge 1 to 6 inches wide, and appears to line up with the contact fault.

CONIAGAS

The Coniagas Mines, Limited, has a capital of \$4,000,000 in shares of a par value of \$5 each. To the end of the year 1922 the company had produced 31,286,744 ounces of silver and had paid \$11,140,000 in dividends.

The company was incorporated in November, 1906; concentration of ore began in September 24th, 1907; and mine ore and concentrates were shipped and treated together during 1907 and 1908.¹

In January, 1920, the Coniagas bought the Trethewey mine and all the company's assets for \$100,000. In 1922 the company leased the Beaver mine, and began operations thereon in January, 1923. The company in 1922 and 1923 were working under option the Ruby mine near North Cobalt.

In addition to its activities in and around Cobalt, the company is developing a gold property at Porcupine, and is interested in other gold claims elsewhere in Northern Ontario.

At the end of October, 1922, there were at the Coniagas mine about seven miles of workings, including drifts, crosscuts, raises, winzes, and shafts.

The company has been treating lower grade ore than any other company in Cobalt. For the year ending October 31st, 1922, the ore averaged 9.19 ounces per ton. The ore hoisted amounted to 123,583.8 tons, from which were received 1,121,279 ounces of silver. The ore was mined and concentrated during the year at a cost of 32.64 cents per ounce of silver content. This cost includes all overhead expenses, royalties, and other general expenses, but excludes the cost of smelting, refining, shipping and marketing, which amounted to 7.64 cents per ounce. The average cost of silver produced during the past 15 years, including all charges above mentioned, has been 23.87 cents per ounce.²

The low cost of operation is partly due to the immense width of some of the stopes, partly to the fact that mine and mill are encompassed within an area of but 17 acres, and partly to the excellent management.

It is interesting to contrast the grade of ore in the early days at the Coniagas with the grade at the present time. In the year 1907 the ore averaged \$50 per ton; in the year ending October 31st, 1922, the ore averaged, as pointed out above, 9.18 ounces of silver per ton.

Almost the entire production of silver has come from the northeast part of the property from an area of ground about 17 acres in extent and about 200 feet in depth. The south half of the property has not been productive.

As may be seen from the plans, the veins on the Coniagas form a complex network; included among the big producers are Nos. 2, 18, and 28; of these veins No. 2 is the most important.

In the last few years very little high-grade ore has been found, and the mill has been treating low-grade mill-rock. In the year 1920, the mine produced only five tons of high-grade ore.

The ore has been obtained almost entirely from the Cobalt series, but a very small quantity was won from the Keewatin. The Cobalt series has an average thickness of about 200 feet, although at the west end of the property it pinches out entirely.

The stopes in the Coniagas are the largest in the Cobalt camp. Some of them are 40, 50, and 60 feet wide and, in one instance, that of the stope on vein No. 18, the stope is 85 feet in width. The great width of this stope is due to the fact that several veins join vein 18, and it is at the junction of these veins with

¹Annual Report, Coniagas Mines, Limited, 1918, p. 11.

²Annual Report, Coniagas Mines, Limited, year ending October 31st, 1922, pp. 4-5.

vein 18 that the stope attains a width of 85 feet. Many of the veins in this stope were small, averaging not more than three-eighths of an inch in width.

It has been the experience of the Coniagas mine that the fine-grained conglomerate was more productive of ore of milling grade than was the coarse-grained conglomerate. No doubt the reason for this was that the fine-grained conglomerate was more readily fractured into tiny cracks than was the coarse-grained. The high-grade ore occurs as commonly in the coarse conglomerate as in the fine-grained. It is well to remember that the high-grade ore occurs only in the veins; these average about an inch or two in width. What has been called the low-grade ore, or mill-rock, is for the most part simply the country rock which is fractured into innumerable tiny cracks, into which silver solutions have penetrated, and along which the silver was deposited. The country rock is thus impregnated with silver for many feet on each side of the vein or veins, producing what is locally called mill-rock.

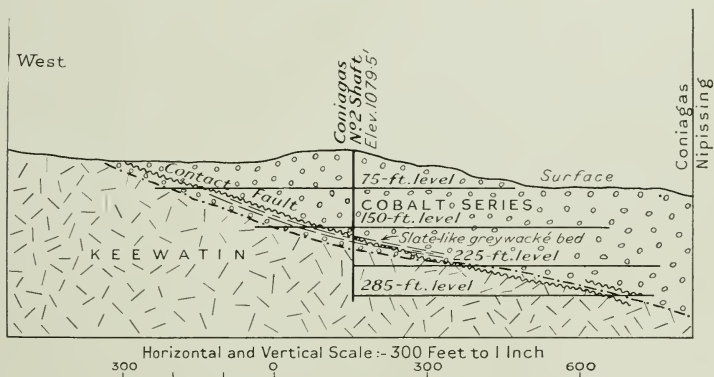


Fig. 20—Vertical section, west 23° north through Coniagas shaft No. 2, showing location of "contact" fault, and its relation to the Keewatin and to a bed of slate-like greywacké.

The "Contact" Fault

An important structural feature of the mine is the presence of a fault which is named on the plans the "Coniagas" fault. This fault is the northward extension of what has been called "contact" fault on the Buffalo. In the following description it will be called the contact fault. On the Coniagas it occurs, for the most part, about ten feet more or less above the Keewatin floor, although in places in the lower levels it passes down into the Keewatin. In other words, this fault is, generally speaking, about parallel to and a little above the contact between the Keewatin series and the Cobalt series; hence the name "contact" fault. The fault dips at an angle of about 16° in a vertical section through No. 2 shaft (Fig. 20). The dip of the contact between the Keewatin and the Cobalt series in the same vertical section is about 14°, or about 2° flatter than the dip of the contact fault.

Silver occurs, as a general rule, above and below the fault where the veins are in the Cobalt series. This statement may be substantiated even now, although the ore is mined out, by examining the great stope in vein No. 69. The fault may be observed on the sides of the stope, some 15 or 20 feet above the level, while above and below the fault it may be seen that the ore has been mined

out. While it is true that the silver ore does occur above and below the fault, it has nevertheless been pointed out by the management that the character of the ore above the fault is different from that below. The management states that more high-grade silver ore occurs above the fault than occurs below; on the other hand, the rock below the fault was found to be a better grade of milling ore than the rock above the fault.

The displacement along the contact fault has not been determined nor has the direction of the movement. The age relation of the fault to the veins has also not been definitely determined, but it would appear that the veins are younger than the faults. One reason for this belief is that the ore below the fault is lower in grade than that above the fault. The writer had no opportunity to study this problem during the time that the veins were being mined along the fault. The same problem regarding the relation of the veins to the contact fault was met with in the properties of the Mining Corporation south of the Coniagas.

The Keewatin floor, on which the sediments of the Cobalt series were laid down, was remarkably uniform, as may be seen by examining the contours of the contact on the map of the Coniagas. Only at one place was much irregularity observed and that was on the 225-ft. level in the vicinity of No. 9 vein.

During May, 1921, the Coniagas mill was treating about 325 tons of ore per day from the mine; the ore contained about 10 ounces of silver per ton. In addition to this, the Coniagas mill was treating about 200 tons a day of tailings from the dump, the tailings containing about 3 ounces of silver per ton. The slimes on the property contain 6 or 7 ounces per ton, and were also being treated by the Coniagas Mines, Limited, but these slimes were treated in the Buffalo mill.

Coniagas Mine Workings

The Coniagas is worked mainly from No. 2 shaft, the elevation of which above sea level is 1,079.5 feet. The mine has 5 levels, namely, the 75-ft., 150-ft., 225-ft., 285-ft., and 375-ft. The lowest level, the 375-ft., is at the extreme southeast corner of the property, and is not connected directly with any shaft, but is entered by means of a winze from the 285-ft. level.

375-ft. Level.—The 375-ft. level was not pumped out at the time of our examination. Less than 200 feet of work has been done on it. The company states that the winze was in conglomerate and greywacké of the Cobalt series. In the crosscut which runs west of the winze, the Keewatin was said to have been encountered 15 or 20 feet west of the winze. The crosscut running northward is said to be entirely in conglomerate. There are no veins reported on this level.

285-ft. Level.—This level produced, relatively speaking, unimportant quantities of silver.

The contact between the Keewatin and Cobalt series may be seen in half a dozen places, and thus its contour is fairly well established. At the north end of the workings, there are two faults which are about parallel to the contact between the Keewatin basalt and the Cobalt series. One of these faults is about 15 feet above the other. The faults are evidently part of the contact fault which is so well developed on all of the higher levels. Possibly at this depth the contact fault has split into two parts, although we were not able to prove this. At the north end of the property, on a sub-level about 10 feet above the 285-ft. level, the most productive vein on the property, No. 2, has been stoped out. The floor of the stope follows about the contact between the Keewatin and Cobalt series on this sub-level. The west face of the sub-level

is Keewatin, and it may be seen that No. 2 vein has pinched out on entering the Keewatin series at this point. Vein No. 65 has a width up to 3 inches of pink calcite; it is a strong-looking vein, but is unproductive as far as explored. A little stoping was done on a vein near the south end of the property.

The Keewatin on the 285-ft. level is a fine-grained basalt. No slate-like greywacké in the Cobalt series was observed on this level.

The only suggestion of the presence of the contact fault at the south end of the property is a calcite stringer dipping 21° eastward; this stringer is a few feet below the contact between the Keewatin and Cobalt series.

225-ft. Level.—On this level the contact between the Keewatin and the Cobalt series has been met with in several places. The contact fault has also been met with in several places; it is partly in the Keewatin series, but mostly in the Cobalt series. At the north part the fault takes a long bend eastward into the Cobalt series. It consists of fault breccia up to 6 or 7 inches wide, and, in extreme cases, a foot or two wide. The gouge is an inch or two wide. In places there is a pink calcite vein as wide as 6 inches in the fault. The fault may be very well studied in the south part of vein No. 69. This vein is located between No. 2 shaft and winze No. 23. We were not able, from actual observation, to determine the direction of the movement on the fault, or for how many feet the rocks had been faulted, nor were we able to determine the relative age of the fault and the vein. It was reported by the management, however, that vein No. 69 came down vertically to the Coniagas fault and that, on encountering the fault, the vein followed the fault down in step-like breaks, until at a distance of about 22 feet southeastward it again took a vertical course and continued down through the conglomerate. The management further reported that in this part of the fault some ore of economic grade was met with.

At the east end of vein No. 23, the fault bears an economic relation to the silver content of the vein; it was reported that no silver was found below the fault, although the vein occurs below the fault.

No well-defined bed of slate-like greywacké was observed on this level, but a poorly-defined bed, shown on the plan, was noted in drift No. 26. This bed probably corresponds to the bed of slate-like greywacké in the big stope on No. 69 vein and to the bed of slate on the 150-ft. level. Greywacké also occurs in crosscut H, about 500 feet from the entrance; it is not clearly enough bedded to make it possible to map.

Veins Nos. 18 and 12, at the north end of the property, apparently pinch out on entering the Keewatin, judging from what may be seen on the level. Vein No. 2, the most productive vein on the Coniagas, may still be seen on the face of the drift at the east end; the ore was not mined here because it is at the boundary of the Nipissing and Coniagas mines. No. 2 vein on the Coniagas is known as the "Fourth of July" vein on the Nipissing. The vein on the east face contains high-grade silver ore, and is about an inch and a quarter in width; the vein contains smaltite, calcite, and native silver. About 8 feet above the floor of the drift, there is a fault which is apparently the contact fault. The vein may be seen at the bottom of the face of the drift, and may be traced up the face about $5\frac{1}{2}$ feet, where it pinches out. The point at which it pinches out is about $2\frac{1}{2}$ feet below the fault. The vein, of course, appears again above the fault, but how far above we were not able to observe. Vein No. 22 at its eastern extremity pinches out to a crack in the conglomerate, and it also pinches out westward in the Keewatin to a mere crack containing calcite here and there about a thirty-second of an inch in width.

Vein No. 9 is interesting on account of the work which has been done on it; but this work was done in order to explore the vein in the Keewatin. The vein was followed in a drift in the Keewatin for 600 feet to the west boundary of the property. It was found to have a width up to 2 or 3 inches, but it did not contain enough silver to pay.

Vein No. 62 at the south end of the property has a width, where it may now be seen, of about half an inch of calcite; it is not a productive vein. Stopping was done at the south end to a height of 22 feet by about 25 feet long.

150-ft. Level.—This level has more work done on it than has any other in the mine. The feature of this level is the great size of stope No. 18, which in one place attains a width of 85 feet. The reason that the stope could be worked to such a width is that there are several veins running into the main vein, No. 18.

No. 9 vein was explored on this level well into the Keewatin series, and while it produced a small quantity of silver, we were not able to ascertain how much; it was, nevertheless, of little importance in the Keewatin. The contour of the contact between the Keewatin and Cobalt series is very regular.

About 10 or 12 feet above the base of the Cobalt series, there is a bed of slate-like greywacké some 8 or 10 feet thick. The bed may be traced on this level for about 700 feet, but we were not able to find a bed on the level below, the 225-ft., which would correspond to it. The bed does go down almost to the 225-ft. level, for it may be seen in stope No. 69 about 15 or 20 feet above the 225-ft. level. The bed was not recognized on the 75-ft. level.

On the 150-ft. level the contact fault follows the top of this bed of slate-like greywacké, except at the south end where it appears to pass down to the lower part of the bed and thence out of it.

Another bed of fine-grained cherty greywacké of a peculiar greenish colour was noted on the eastern part of the workings at veins Nos. 2 and 28. Its location is shown on the plan. This bed is not easy to separate from the other sediments of the Cobalt series; it is structurally about 75 feet above the bed which has just been described.

In July, 1921, the only development work which was being carried on was being done on the 150-ft. level at the south end of the property. A small vein about 35 feet northeast of vein 15 was being drifted on towards the southeast. At the end of the long crosscut near the southwest corner of the mine, another small vein was also being explored.

The south part of the Coniagas property is the only part which has not been thoroughly explored, hence the development work which was being done in July, 1921. The contact fault has been traced for a greater distance on this level than on any other. It has been followed for 1,100 feet, and at neither end had it pinched out. The fault consists of a fault breccia and gouge 4 or 5 inches in width; there is always more fault breccia than gouge in the fault. In places the fault breccia is 2 feet or more in width. Practically all of the 150-ft. level is accessible, except the last part of vein No. 2 and part of vein No. 18.

75-ft. Level.—Much of the level is inaccessible as the floors have been stoped out, and there is generally no timber to allow the examination of the parts so mined out. The contact between the Keewatin and the Cobalt series was cut only in one drift, that which follows vein No. 4. The contact fault, however, was encountered in five drifts and has been traced for 500 feet; the fault has not pinched out at either end.

KERR LAKE

The Kerr Lake Mines, Limited, has a capital of \$2,400,00 in shares of a par value of \$4. The company has produced 27,005,276 ounces of silver, and has paid \$10,195,000 in dividends to the end of the year 1922. The property was closed on February 1st, 1922.



Fig. 21—Showing stopes in veins in bed of Kerr lake.

The cost of producing silver for the year ending August 31st, 1920, was 56.04 cents per ounce, including mining, developing, shipments, treatment, administration and general expenses; for the year ending August 31st, 1919, the cost was 40.81 cents an ounce, and for the previous year it was 24.74 cents.¹

The total development work, including drifts, crosscuts, raises, winzes, and shafts, amounts to 12.2 miles.

The vein-system on the Kerr Lake and Crown Reserve is a continuous one, the boundary lines of the claims being accidental. Some of the veins on the Kerr Lake extend into the Crown Reserve, notably the Big Chamber, which is known as the Carson on the Crown Reserve; No. 10 which is known as the Ross on the Crown Reserve; and the Fleming which is known by the same name on the Crown Reserve.

The principal veins on the property are No. 10, No. 3, Fleming, No. 7, Big Chamber, Main East, and McDonald. A separate record of the production of each vein was not kept until the fiscal year ending August 31st, 1911; consequently the figures in the following table are not complete, but nevertheless serve a useful purpose. No. 3 vein at the southeast corner of the mine was one of the most important veins on the property and one of the first discovered. By August 31st, 1910, it was almost mined out, so that the production figures given in the following table have been estimated. The company has informed the writer that No. 3 vein produced between two and three million ounces of silver.

PRODUCTION OF INDIVIDUAL VEINS, KERR LAKE MINE, AUGUST 31ST, 1910,
TO AUGUST 31ST, 1921²

Name of Vein	No. of Ounces Produced
No. 10.....	3,345,233
No. 3.....	3,000,000 ³
Fleming.....	2,217,512
No. 7.....	2,029,518
Big Chamber.....	1,488,401
Main East.....	932,352
McDonald.....	867,401
No. 3 Lake.....	557,584
No. 15.....	463,740
No. 8.....	279,290
Xmas.....	207,146
No. 3 Lake North.....	114,501
Little No. 3.....	89,757
No. 2.....	82,660
No. 218 Side.....	42,712
No. 21.....	34,542
No. 218.....	22,847
Little No. 7.....	29,796
South No. 10.....	22,243
No. 2 Lake.....	16,657
Cross.....	11,405
Keewatin.....	9,087
No. 21 Side.....	5,602
No. 7 Side.....	5,301
Split vein.....	3,140
No. 3A.....	3,000
No. 18.....	2,410
Little McDonald.....	2,393
No. 23.....	1,603
Crusher.....	1,560
No. 17.....	1,526
No. 2.....	1,315
No. 6.....	930
No. 19.....	152
No. 20.....	150
No. 16.....	100

¹Annual Report, Kerr Lake Mines, Limited.

²Annual Reports, Kerr Lake Mines, 1911-1921.

³Estimated at two to three million ounces.

No. 3 vein at the southeast corner of the property is one of the most interesting in the camp. The vein occurs in the Nipissing diabase and passes down into the Keewatin, in which formation it has been explored by workings for 150 feet below the diabase. The vein proved productive, however, only in the Nipissing diabase. Even in the diabase the ore-shoot did not extend to the bottom of the sill, but came to within about 125 feet of the bottom. The stope-section, showing the ore-shoot and its relation to the diabase and Keewatin, is printed on Sheet No. 31a-3, on which are published the plans of the Kerr Lake and Hargrave mines. Assuming that the diabase has a thickness of about 1,000 feet, it will be seen from the stope-section that the ore-shoot extends upwards into the middle of the sill. It may have continued to the top of the sill, but this part has been, of course, long since eroded. At any rate this is the only instance in the Cobalt camp proper in which an important ore-shoot occurs in the centre of the diabase-sill. On the 550-ft. level, No. 3 vein in the Keewatin contained some gold at one point; assays of \$1 to \$18 were obtained.¹

The No. 3 vein was very rich on the surface; the vein above the adit level up to the surface produced 170 tons averaging \$1,500 per ton.²

Here and there along the walls of No. 3 vein there are striations dipping gently to the south, proving that some more or less horizontal movement took place along the fracture in which No. 3 vein occurs.

At the south end of the Kerr Lake property, the No. 3 vein splits into two branches and these branches continue south into the Hargrave.

Vein No. 7 had an ore-shoot about 700 feet long.³ An idea of the richness of the ore in this vein may be obtained when it is considered that on the 140-ft. level a drift 60 feet long in the No. 7 vein produced 94,000 ounces of silver.

The Big Chamber vein has a length of about 175 feet on the 140-ft. level. It extends into the Crown Reserve where the vein is known as the Carson, the length of which was about 275 feet. The total length of the vein on the Carson and Kerr Lake is about 450 feet. The Big Chamber produced at least 1,488,401 ounces of silver, the records of production of this vein not being complete. On the Crown Reserve the vein produced over nine million ounces which was nearly half the production of the entire Crown Reserve mine.

The plans show that at the west part of the Kerr Lake mine there is a trough in the Keewatin. The axis of the trough pitches and strikes to the north. This trough or depression is best shown on the 140-ft. level. If the plan of this level be joined to the plan of the 100-ft. level of the Crown Reserve the outline of the trough will be brought out better. This trough appears to have been formed by erosion and later filled in with the Cobalt series. It does not seem to have been formed by folding after the Cobalt series was laid down, because the lower bed of slate-like greywacké, shown on the 140-ft. level of Kerr Lake and the 100-ft. level of Crown Reserve, does not conform with this deep trough. If the reader will examine these plans he will more readily grasp what is meant.

The veins in the Crown Reserve and Kerr Lake not only cross the trough, but run down the axis of the trough. Indeed, the veins have a variable strike. It would appear to the writer that the main factor governing the fractures in these two properties is their occurrence below the Nipissing diabase dome, shown in the vertical section facing page 34.

Difficulty was experienced in deciding as to where the contacts between the Keewatin and Cobalt series should be located. Where the Cobalt series rests on Keewatin basalt the contact was transitional, and therefore difficult

¹Annual Report, Kerr Lake Mines, Limited, for year ending August 31st, 1921.

²Report to Directors of Kerr Lake Mining Company by W. J. Barrett, November, 1906.

³Annual Report, Kerr Lake Mining Company, year ending August 31st, 1909, p. 2.

to place. On the other hand, where the Cobalt series rests on Keewatin cherty "iron formation", at the northeast corner of the property, the contact was sharp, and more easily placed. The company's plans showed some of the contacts, which were worked out by Mr. G. R. Whitman; these plans were of assistance.

The company obtained most of the silver from veins under Kerr Lake, with the exception of the silver which No. 3 vein at the southeast corner of the property produced. The plan of the adit level shows the strip of land under Kerr Lake.

A description of how and when the water was pumped out of Kerr lake is given elsewhere in this report.

The mine has been operated from No. 7 shaft at the northwest part of the claim, and from No. 3 shaft at the southwest corner; No. 3 shaft was used mainly in mining No. 3 vein.

Kerr Lake Mine Workings from No. 7 Shaft

The mine workings from No. 7 shaft are described below. Most of the ore came from veins operated from this shaft.

325-ft. Level from No. 7 Shaft.—This level was run in Keewatin and was not accessible. It is reached by a winze from the 275-ft. level, and has little work done on it. The level was run on the Fleming vein where a short shoot of fair ore was met with. The rest of the vein is barren.

275-ft. Level from No. 7 Shaft.—The east part of the level was not accessible; it is reached by a winze from the 225-ft. level, and has little work done on it. The rock is Keewatin and the drift followed the Fleming vein, which showed ore of fair milling grade with occasional spots of high-grade for over 200 feet.

The west part of the level was examined and found to consist entirely of Keewatin, together with a narrow bed of banded Keewatin "iron formation" striking southwesterly.

225-ft. Level from No. 7 Shaft.—The Big Chamber vein, the eastward extension of the Carson vein on the Crown Reserve, is entirely in Keewatin on this level. The Fleming vein is partly in Keewatin and partly in Cobalt series; that part in the Keewatin produced some high-grade ore.

The bed of Keewatin "iron formation" found on the 275-ft. level also occurs on the 225-ft. level. It is highly impregnated with zinc blende and iron pyrites. The Cobalt series forms a belt from a few feet up to 135 feet in width at the north boundary of the property.

165-ft., 175-ft., 190-ft. Levels from No. 7 Shaft.—These levels may, for descriptive purposes, be treated together. The Fleming vein has been followed for over 600 feet, and it may still be seen in the back of the stope in places where it is as wide as 15 inches. The vein dips at 67° to the south. Near the east end of the vein there is a fault dipping 60° to 79° eastward which apparently cuts off the silver content of the Fleming vein. The fault contains iron pyrites, calcite, and quartz, and is rusty. In places the iron pyrites in the fault is banded, as many as 40 bands having been counted. The character of the fault varies from point to point. Where it meets the Fleming vein it consists of two inches of calcite, four inches of iron pyrites, banded, and half an inch of gouge. In other places the fault has only a little calcite together with gouge and fault breccia. The age relation between the vein and fault was not determined.

At the northeast corner of the level the Keewatin consists of black, carbonaceous chert. At the west part there is a trough in the Keewatin floor, now filled with Cobalt series. This trough is more pronounced in the level above.

140-ft. Level from No. 7 Shaft.—This is the most comprehensive level in the mine, giving as it does a good idea of the complexity of the vein-system. The level is about the same elevation as the 100-ft. of the Crown Reserve, the levels being connected along the Carson vein. The barren parts of the Fleming vein have a width of 12 to 15 inches.

The trough in the Keewatin at the west end of the mine is well defined on this level. No. 7 vein follows along the east side of the trough and then turns westward and crosses the trough.

At the east end of the level the Keewatin consists of chert; where the bedding of the chert may be seen, it is about vertical. The chert is impregnated with iron pyrites, zinc blende, and galena, and is also carbonaceous.

A fault occurs at the northwest corner of the level. It dips 32° northward and has a reverse displacement of at least five feet.

90-ft. Level from No. 7 Shaft.—Most of the level is Cobalt series. At the south end some work has been done in the Nipissing diabase which shows that the contact of the diabase and adjacent rocks is an unusually irregular one. What is known as the "office" vein, consisting of smaltite and calcite, was not productive of silver. No. 7 vein consists of several parallel veins which join together into one or branch again into several veins.

Kerr Lake Mine Workings from No. 3 Shaft

Vein No. 3 is worked from this shaft; it was one of the most important veins in the property. The ore-shoot was wholly in the Nipissing diabase, but the lower levels were used to explore and prospect the vein in the Keewatin below the diabase. The seventh, eighth, and ninth levels are worked by a winze from the sixth level.

Ninth Level, 550 Feet below Collar of No. 3 Shaft.—This level was examined on June 6th, 1921. At that time the drift on No. 3 vein was about 60 feet in length. North of the winze the vein averaged about four inches in width. South of the winze the vein became smaller and on the face was half an inch wide. A little galena occurs in the vein. The vein assayed at one place 54 ounces of silver, but the average grade on the level was too low to pay. In the winze the vein was four or five inches in width, consisting of calcite. The rock on the ninth level consists of Keewatin cut by an 18-inch lamprophyre dike. The dike is north of the winze and dips 10° to 20° southeast.

Eighth Level, 420 Feet below Collar of No. 3 Shaft.—No. 3 vein on the eighth level pinches and swells, and varies in width from one to five inches. It consists mostly of calcite, together with a little smaltite in spots. On the north face of the drift there were three veins in the face, one of which was two inches wide while the others were narrower. The vein was barren of commercial ore.

Seventh Level, 370 Feet below Collar of No. 3 Shaft.—No. 3 vein between the winze and the north face of the drift is a strong vein averaging three or four inches and up to eight inches in width. A little native silver was found, but no ore of commercial importance was met with. The contact of the diabase and Keewatin is at the north end of the drift. The contact dips between 80° to 90° to the north. The Keewatin at the contact is chert. The No. 3 vein splits and almost pinches out on descending into the chert, although six feet from the contact it is five or six inches wide in the diabase. At the south end the drift goes into the Hargrave.

Sixth Level, 320 Feet below Collar of No. 3 Shaft.—On this level considerable crosscutting was done to explore the ground. About half a dozen veins were

encountered and drifted on, but were of little value. This was the lowest level on which No. 3 vein was productive.

Fifth Level, 272 Feet below Collar of No. 3 Shaft.—The level is all run on No. 3 vein, except at the north end where an exploratory crosscut extended north into the Keewatin. On the walls of No. 3 vein, there are scratches and striations dipping gently southward, showing that some horizontal movement has taken place along the walls of the fracture in which the vein occurs.

Fourth Level, 224 Feet below Collar of No. 3 Shaft.—The level is all diabase except at the northwest corner where a drift follows a vein containing smaltite and iron pyrites.

Third Level, 179 Feet below Collar of No. 3 Shaft.—This level consists of a short drift along No. 3 vein, all in Nipissing diabase.

Second Level, 123 Feet below Collar of No. 3 Shaft.—This is an extensive level which is connected with No. 7 workings by a raise from the northwest corner. On the walls of No. 3 vein there are scratches and striations dipping 10° to 20° south.

First Level, 67 Feet below Collar of No. 3 Shaft.—This is a small level consisting of a short drift on No. 3 vein.

HARGRAVE (KERR LAKE)

The Hargrave was bought by the Kerr Lake Mines, Limited, for \$16,500 during the company's fiscal year ending August 31st, 1921. After the Kerr Lake Mines acquired the property, the mine produced 35,973 ounces of silver.

According to the records of the Ontario Department of Mines, the Hargrave property produced 506,972 ounces of silver.

During the time that the property was being worked by the Kerr Lake Mines, the writer had an opportunity of examining some of the workings contiguous to the Kerr Lake property on the south. These workings are on the southward extension of the No. 3 vein and its branch.

No. 3 vein on the Kerr Lake produced between two and three million ounces of silver, but unfortunately the ore-shoot scarcely extended into the Hargrave, although the two branch veins of calcite did extend to the south as far as the Hargrave workings had been driven. The stope-section of No. 3 vein is shown on the Kerr Lake-Hargrave Sheet, No. 31a-3. It will be seen from this section that a very small part of the ore-shoot at the top and at the bottom extended into the Hargrave.

The cause of the cutting off of the ore-shoot to the south is not certainly known, but a fault, which was best seen on the 375-ft. level of the Hargrave, may have been a factor in the matter. Very little ore is reported to have occurred to the south of the fault.

The seventh level of the Kerr Lake mine was extended south into the Hargrave workings, as shown on the plan of the sixth and seventh levels of the Kerr Lake mine. No. 3 vein splits, and branches were drifted on for about 100 feet. This level had not been directly connected with the Hargrave shaft No. 3. The rock is all Nipissing diabase, which is considerably disturbed in places, the numerous joint planes in the rock being polished and striated. A small shoot of ore was found in the east branch of No. 3 vein above the level, yielding 35,973 ounces of silver.

The 375-ft. level of the Hargrave is an extensive one. The writer examined that part of it south of the Kerr Lake. On this level there is a fault striking a

little east of south and dipping almost vertically. The fault cuts across No. 3 vein about 20 feet south of the boundary line. The east branch of No. 3 vein gradually converges toward this fault, and enters the fault at a very gentle angle. On the seventh level this fault was not a clear-cut fracture, but appeared to be represented by the crushed and striated diabase referred to in the preceding paragraph.

The writer did not have an opportunity of examining the fault on the higher levels of the Hargrave mine. It would have been of interest to see what relation the fault had to the ore-shoot on No. 3 vein in the upper part of the mine.

The Hargrave workings east of the Kerr Lake claim were not examined.

LA ROSE MINES

La Rose Mines, Limited, has a capital of \$1,500,000 in shares of a par value of \$1.00; all the stock has been issued. The company has produced 25,897,914 ounces of silver, and has paid \$7,655,410 in dividends to the end of the year 1922.

The company owns La Rose mine, La Rose Extension, the Violet, the Princess, the Lawson, the University, and the Fisher-Eplett. Most of the production has come from La Rose.

The writer is indebted to Mr. G. C. Bateman, manager of La Rose mine, for the figures giving the shipments from La Rose, Lawson, University, Princess, and Violet.

La Rose

La Rose mine was not working during the time of examination and, moreover, the workings, with the exception of the tunnel levels, were flooded. The plans of the mine in the pocket at the back of the report show the geology of the tunnel levels. This geological mapping was done by Mr. James Hill.

It was a source of regret to the writer that he was not able to examine this historic mine. The main vein was one of the first found at Cobalt, the McKinley-Darragh being the first for which an application was sent to the Government. The main La Rose vein was the first one in the camp to have a blast put in it.¹

La Rose mine produced 17,479,977 ounces of silver to the end of the year 1922.

The report of the company to the shareholders dated June 20th 1908, contains three reports from three different sources on the operations of the company up to that time. These and later annual reports of the company give excellent descriptions of the property. The main vein was the most important one. On the 62-ft. level this vein had an ore-shoot about 850 feet long, which averaged about 700 to 1,000 ounces to the ton from ore taken from the drift in this level. It was richer in other places, assays from 3,000 to 14,000 ounces having been obtained. The vein really consisted in places of two to four roughly parallel veins and the average width of ore was 8 to 12 inches. The vein has, according to the descriptions in the annual reports, been faulted here and there by minor faults.

Cobalt Lake Fault

The Cobalt lake fault is a reverse one with a displacement of approximately 275 feet. At the McKinley-Darragh the displacement is greater. It has been

¹W. G. Miller in the Report of La Rose Consolidated Mines Company, June 20th, 1908.

prospected down to the 665-ft. level, as indicated on the vertical section facing page 8. No ore of commercial grade was found in it, although a large calcite vein was discovered in places. On the 380-ft. level the fault was drifted on for 500 feet; a strong vein of calcite, in places three feet wide, lies along the fault. It carries silver throughout, but no high-grade ore has been developed. On the 500-ft. level the fault was followed for 130 feet and a large calcite vein was found which carried only a small quantity of silver. An inclined shaft was sunk on the fault for a distance of 233 feet below the 500-ft. level. Near the bottom, at a depth of 215 feet, drifts were run both ways for a combined length of 80 feet. No ore of commercial importance was found.¹

Relation of Cobalt Lake Fault to Main La Rose Vein

The writer has not had an opportunity of investigating the age relation between the main La Rose vein and the Cobalt lake fault; nor are there any published descriptions concerning this question. It was learned, however, from those in charge of operations, that the vein extended into the fault at the north and south ends. The vertical section facing page 8 shows the vein extending down vertically into the fault. It would appear therefore that the vein is really a branch fracture of the Cobalt lake fault and that this branch fracture rises up vertically from the fault. Certain it is that the main La Rose vein has not been found on the west side of the fault, although it has been diligently searched for in La Rose, La Rose Extension, Chambers-Ferland, and Right of Way mines.

McDonald and No. 3 Veins

There are several other veins on the La Rose, chief of which are the McDonald and No. 3 veins. These strike eastward and southeastward, or about at right angles to the main vein. The McDonald extends into the O'Brien, thence eastward across the O'Brien and possibly into the Violet mine. The combined length of the McDonald vein on the three properties is about two-thirds of a mile, probably the longest vein-system in Cobalt; the ore-shoots are not continuous for the whole length. On the O'Brien the vein is known as No. 1. It should be added here that No. 1 vein on the O'Brien had not been connected up by mining operations with the Violet veins, and therefore it cannot be definitely said that No. 1 vein on the O'Brien extends into the Violet.

The McDonald vein has a stope at least 445 feet long,² while on the O'Brien the stope is 900 feet long, making a continuous ore-shoot at least 1,345 feet long.

No. 3 vein persisted from the Cobalt series into the Keewatin, and contained high-grade into the Keewatin at least to the 135-ft. level of No. 3 shaft. On the 236-ft. level the vein was small and low-grade.

Fault 64

The fault known as "No. 64" has been followed in a tunnel at the northeast corner of the claim. The fault is a normal one with a displacement of about four or five feet, the south side being the downthrow side. There is a fault breccia a foot wide in places, and the fault is about vertical. A vein occurs in this fault for a distance, after which it leaves the fault and turns southwestward into the Chambers-Ferland. The fault lines up with the O'Brien and Violet

¹Sixth and Seventh Annual Reports, La Rose Consolidated Mines Company, for years 1913 and 1914.

²Third Annual Report, La Rose Consolidated Mines Company, for year ending May 31st, 1910, p. 10.

faults (Fig. 8). It is supposed also that it extends westward into the Chambers-Ferland, Nipissing, and Hudson Bay; but as the fault has not been followed by mine workings through the Cobalt lake fault, it is not known definitely that it is continuous across all the above properties.

La Rose Extension (La Rose)

La Rose Extension has not produced any silver, although considerable work has been done on it. The writer examined what is called the 380-ft. level on May 3rd, 1923. This level is 340 feet below the collar of No. 10 shaft and is reached from the shaft. The level is all in Cobalt series. A major fault was met with in three crosscuts north of the shaft. The fault dips at 58° to 62° southeastward; its location is shown on the plan of this level. In the first crosscut north of the shaft, the rocks are crushed for about 100 feet in the vicinity of the shaft.

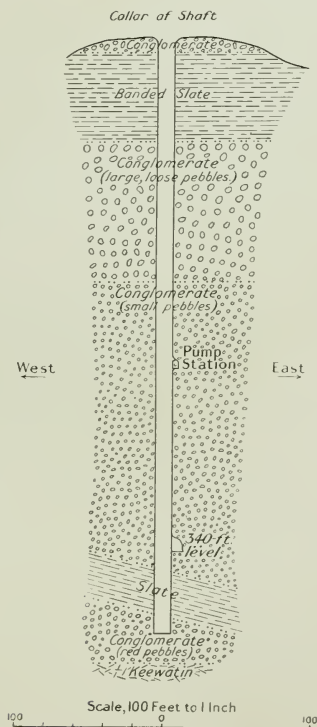


Fig. 22—Vertical section through No. 10 shaft on northwest part of J.B. 4, La Rose Extension, furnished by La Rose Company. The shaft was not geologically examined by the Ontario Department of Mines. The rocks in the shaft are reported to belong to the Cobalt series.

Violet (La Rose)

The Violet is east of and contiguous to the O'Brien. It has produced 404,204 ounces of silver to the end of the year 1922. On the surface on the west part of the property there were no veins exposed, but, as the O'Brien was mining ore bodies near the Violet boundary, La Rose management decided to sink a shaft and explore the ground east of the O'Brien. This shaft was sunk to a depth of over 410 feet and levels established at 330 and 410 feet, with two sub-levels at 250 and 315 feet. At the 410-ft. level, a winze was sunk over 600 feet below the collar of the shaft and levels established at 470, 530, and 600 feet.

A lawsuit having determined that this shaft was on the O'Brien property, La Rose management decided to sink another shaft, which on our plans is named the "new shaft." The new shaft was finished to the 600-ft. level by the spring of 1923, and connected with the 600-ft. level of the winze from the old shaft.

The work from the two shafts proved the existence of two main veins. No. 5 vein strikes eastward. No. 3 vein strikes southeastward and dips about 65° to the southwest.

There is a bed of Keewatin "iron formation" striking a little west of north on the 330-ft. level. This bed was also encountered in the O'Brien and at points farther westward. The "iron formation" dips steeply to the south.

The Violet fault probably follows the strike and dip of the "iron formation." In fact this fault, which extends westward to the O'Brien, La Rose, Chambers-Ferland, Nipissing, and Hudson Bay, appears to follow the bed of "iron formation" across these properties. Neither the fault nor the "iron formation" has, however, been traced continuously across these properties. The fault dips at 80° to 90° to the south and has a fault breccia 2 to 14 inches wide.

600-ft. Level.—This level was not accessible at the time of examination, but No. 3 vein is reported to have been met with and high-grade ore and mill-rock encountered in the drift.

530-ft. Level.—No. 3 vein appears to follow a narrow lamprophyre dike. There is much pyrite in the Keewatin near the shaft.

470-ft. Level.—The No. 3 vein has been drifted on for over 500 feet and it may be seen to pass from the Keewatin to the diabase. The isolated area of Keewatin on this level appears to be a great included block of Keewatin basalt caught up in the Nipissing diabase. The new shaft penetrated and passed through this block of Keewatin, as shown in the coloured section facing page 8.

330-ft. Level.—The structure in parts of this level was rather difficult to work out. The crosscut running north of the shaft followed about the base of the Cobalt series, and the contact between the Keewatin and the Cobalt series was transitional; the contact was consequently difficult to locate. About 20 feet north of the shaft the conglomerate and greywacké of the Cobalt series were met with, and these rocks were followed in the crosscut for about 135 feet, at which point fine-grained cherty beds of silicious sediments belonging to the Keewatin "iron formation" were encountered and followed to the north for 160 feet in the crosscut. The cherty sediments are in most places finely bedded; they strike eastward, and dip to the south at steep angles, 70° to 80°.

About 165 feet north of the shaft a vein, No. 5, was met with, striking east and west. This vein was followed for about 420 feet. It is, in places, a strong-looking vein one to five or six inches wide, although towards the east it averages in places less than a quarter of an inch. It consists mainly of calcite, but a short distance east of the crosscut the vein consists of two or three inches of smaltite. It has been stoped at the west end.

The rocks along the drift following No. 5 vein consists largely of fine-grained cherty beds of the Keewatin "iron formation," which are cut by dykes of lamprophyre.

The conglomerate and greywacké in the crosscut, and in the drift on No. 5 vein, have a brownish colour, which gives the rock an uncommon appearance.

The Violet fault was met with about 90 feet north of the shaft.

315-ft. Level.—This is a small sub-level on vein No. 5 above the west end of the 330-ft. level. The Violet fault was also encountered in this level.

250-ft. Level.—This is a sub-level which is reached by a raise from the 330-ft. level; the raise follows No. 5 vein. The contact between the Keewatin series and the Cobalt series is about 30 feet above the 330-ft. level in this raise.

The 250-ft. level in a general way follows the contact between the Nipissing diabase and the conglomerate and greywacké of the Cobalt series. The dip of the contact of the diabase is steep between the 250-ft. and 330-ft. levels.

On this level the Violet fault has been followed for about 100 feet. As nearly as may be determined, the fault strikes southeastward and dips at about 80° to the southwest. It consists of two to 14 inches of gouge and fault breccia and in places contains galena. Here and there it carries as much as 10 per cent. of galena, the remaining part of the fault consisting of gouge and crushed rock. The only level on which the fault intersects the No. 5 vein is the 250-ft. At the west end the vein continues up to the fault, but does not apparently occur on the southwest side of it. About 65 feet westward down the vein, a vein occurs on the southwest side of the fault, but whether this is the faulted part of No. 5 vein, or another vein, could not be determined at the time of the examination, the back of the drift being about 20 or 25 feet above the floor.

90-ft. Level.—This level is reached from a shaft at the south part of the claim. It was not accessible at the time of examination.

Princess (La Rose)

The Princess mine is west of and contiguous to the McKinley-Darragh. The property has produced 3,713,806 ounces of silver to the end of the year 1922.

Scarcely any of the veins came to the surface; they pinch out to mere cracks before they rise to that height.

The mine has been worked from four levels, namely, the first, second, third, and fourth; these levels are respectively 45, 132, 185, and 230 feet below the collar of the shaft.

A very interesting structure occurs on the lower levels. There is a vein on these lower levels which is limited as to depth by the Keewatin below, and as to height by the contact fault. The fault is about 12 feet above the contact, so that the vein is only 12 feet high; it pitches down along the Keewatin floor as far as the workings had extended on August 2nd, 1921. Up to the date mentioned, the vein was said to have produced \$50,000 in silver. This vein is another of the numerous examples which show how the ore follows the Keewatin contact. In this case the ore rises an exceptionally short distance above the Keewatin.

The levels, beginning with the lowest, are described below:—

Fourth Level.—This level had about 500 feet of crosscuts and drifts up to August, 1921. The main crosscut follows in a general way the contact between the Keewatin and Cobalt series. A fault just above the contact is well exposed by the workings. It occurs from a few feet to about 12 or 15 feet above the Keewatin floor. This fault is of economic importance on this level because it

completely cuts off vein No. 405; that is to say, the vein has not been found above the fault, and the ore is cut off in the Keewatin below. Above the fault there occurs a thick bed of quartzite.

In the vicinity of this vein the succession of the sediments of the Cobalt series is as follows: On the Keewatin rests a bed of conglomerate about 12 or 15 feet thick; this is followed by a somewhat ill-defined bed of slate-like greywacké, a foot or two wide; above the slate is a thick bed of quartzite. The contact fault follows the bed of slate-like greywacké.

From the fourth level an inclined winze along the Keewatin floor was being sunk on the vein in August, 1921, and on the second day of that month the winze was down about 30 feet. On the face at the bottom of the winze, the vein was a strong one, two to eight inches wide, consisting of calcite, smaltite, and some native silver.

The vein appears to be younger than the fault, as it does not show any drag, nor is it disturbed by the fault. The fracture in which the vein occurs does not extend upward through the fault into the thick bed of quartzite above the fault. Perhaps the thick, massive bed of quartzite was too unyielding to allow the fracture to extend into it; or perhaps the fault was the controlling factor which prevented the fracture from extending upwards into the quartzite. A search for the vein above the fault failed to locate it.

Third Level.—An interesting feature of this level is the development work which has been performed on the Cobalt lake fault, the only level in the mine in which the Cobalt lake fault has been encountered up to the time of our examination. The fault has been drifted on for over 200 feet. At the northeast end of the fault masses of pure smaltite occur in the fault. One of these is 18 inches in length by about 8 inches wide. It is roundish in shape and striated and polished. There are scores of these masses of smaltite in the fault. The curious thing about them is that they are all roundish, polished, striated, and slickensided, as though they had been disturbed by a late movement which took place in the fault after the smaltite was deposited. The length of that part of the fault containing the smaltite masses is 25 or 30 feet. This is the only spot in the Cobalt lake fault in which the vein has been disturbed by movements in the fault after the ore was deposited. Cobalt bloom is profusely developed in this part of the fault. Beyond this, to the southwest, cobalt bloom occurs here and there along the gouge of the fault. The company sampled the entire length of the drift in which the fault occurs and found that the rock averaged about three ounces of silver per ton.

The contact fault is well developed in this level.

In some of the Keewatin workings, in line with vein No. 405, there is a fault consisting of gouge and crushed rock an inch or two wide dipping steeply to the southwest. In it here and there is a vein of calcite and a little quartz, less than an inch wide. This fault vein may be the downward extension of vein No. 405 into the Keewatin.

Sub-level.—What is known as the sub-level, or intermediate level, is about 20 feet below the second level. There is a network of veins on this level, and some stopes of considerable size, 10 to 20 feet or more wide. The workings on this sub-level are most irregular.

Second Level.—Much of the second level is inaccessible; the southwest part, for instance, having quite extensive crosscuts which are now dammed off by concrete dams. We were not able to examine these workings; the information regarding the location of the contacts between the Keewatin and Cobalt series was kindly furnished by the company. Where we could see the contact of the

Keewatin and Cobalt series it was found to be irregular; that is to say, the Keewatin floor was weathered into valleys and hills, which were filled with conglomerate.

The contact fault was found at two places dipping 25° southeastward; other places where it should normally be found were inaccessible.

The main veins on the property are found on this level, and have stopes on them 15 or 25 feet wide in places.

First Level.—The first level is not important, there being only a small amount of work accomplished.

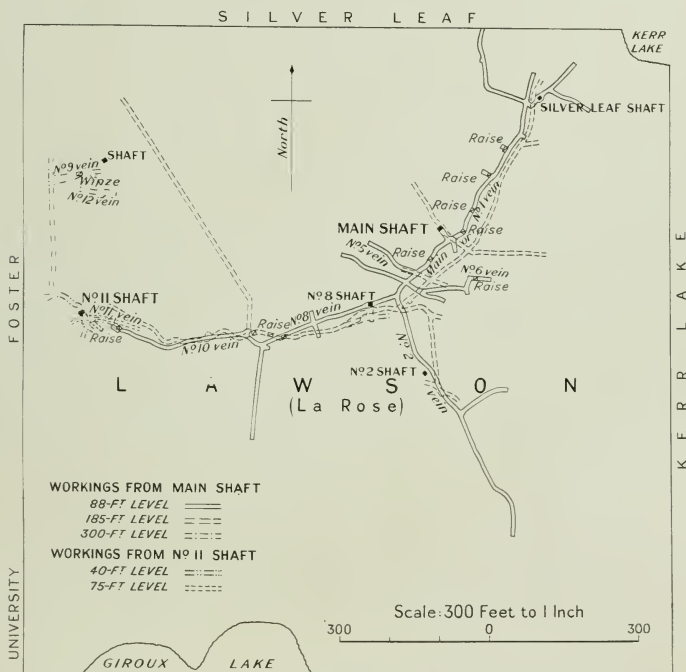


Fig. 23—Plan showing mine levels at Lawson (La Rose).

Lawson (La Rose)

The Lawson was not working at the time of our survey, and no examination was made. The plans of the levels (Fig. 23), were kindly furnished by the company. The property produced 4,213,553 ounces of silver to the end of the year 1919. Some of the veins yielded exceedingly rich ore.

The following summary of the work at this property was obtained from the annual reports of La Rose.

The development of the main vein, No. 1, proved disappointing; the ore body which promised so much at the outcrop held its value only to a shallow

depth.¹ Veins Nos. 2, 5, and 8, 9, and 11 developed good ore-shoots. No. 2 vein is in Keewatin and had an ore-shoot on the 88-ft. level 140 feet long. A stope on No. 5 vein was 130 feet long in the year 1910. On vein No. 8 at the 188-ft. level an ore-shoot of very high-grade ore, 80 feet long, was opened up. No. 9 vein on the first level had a shoot 70 feet long, about four inches wide, assaying 2,000 to 3,000 ounces of silver per ton.

In the year 1911, the mine produced 1,321,000 ounces of silver. A small shoot of ore assayed 9,656 ounces of silver per ton. The ore in this vein occurs in small, rich pockets.

No. 5 vein and the main vein proved barren on the 400-ft. level.

At the end of the year 1915, all the known ore had been mined. The mine was closed in 1917, but ore from the surface dumps was still being shipped.

University (La Rose)

The University property produced 879,599 ounces of silver to the end of the year 1922. At the time of examination in 1920 and 1921, the old workings at the east end of the claim, adjacent to the Lawson, were not being operated. The workings at the west part, from the shaft near the shore of Giroux lake, were, however, being operated.

The structure of the rocks at the University mine is illustrated in the vertical section facing page 40. This section, which is drawn through the University shaft at the west part of the property, extends northward through the Penn-Canadian shaft. At the University shaft, the Nipissing diabase forms an arch; north of the shaft the diabase dips at some 45° to the north, while south of the shaft it dips to the south at about the same angle. The structure has the appearance of an anticline, but it is evident that this anticline-like structure has not been caused by folding. Had folding caused the formation of the arch, the Cobalt series below the arch would also have been folded into an anticline. This is not the case, as is shown by the vertical section. Indeed, the Cobalt series below the arch has been folded the opposite way into a gentle syncline or basin.

The writer believes that the Nipissing diabase sill was intruded from the southeast towards the northwest in the form of an arch, and that, in the vicinity of the University shaft, it first ripped upwards across the bedding of the sediments of the Cobalt series, then turned downwards at a right angle forming an arch. It then very soon flattened out, and, when it reached the Bailey and Penn-Canadian, it selected a single bed in the slate-like greywacké and followed this bed for some distance.

The Cobalt series around the University shaft is not thick; in the section referred to is it about 135 feet. There is a basal conglomerate about 50 feet thick, followed by a bed of slate-like greywacké 70 feet thick, and at the top a bed of quartzite about 15 feet thick. These dimensions are approximate.

The bed of slate-like greywacké is the productive formation. Although the veins extend down into the conglomerate, no silver of importance has been found in the conglomerate.

The vein-system is a short one striking northeastward. There are five comparatively small levels at 60, 90, 110, 120, and 145 feet below the collar of the shaft.

On the 145-ft. level, an exploratory crosscut was run northward. It passed first through Keewatin basalt and then encountered conglomerate of the Cobalt

¹Third Annual Report, La Rose Consolidated Mines Company, for year ending May 31st, 1910.

series which did not come down to the floor of the drift. There is a gradual transition between the Keewatin basalt and the conglomerate of the Cobalt series which made it difficult to place the contact. The diabase dips at 34° northward.

The 110-ft. and 120-ft. levels are very small, consisting of a drift on the vein-system. The 60-ft. level consists of a stope in the bed of slate-like greywacké.

At the east end of the University, La Rose company did some work in 1914 by running a crosscut from the Lawson mine into the University to cut No. 1 vein opened up in the old workings. The ore exposed by the old University company on this vein was sampled and found to be generally low-grade. Subsequent shipments were made, and 1,479 tons were milled and found to yield 17.42 ounces per ton. No. 2 vein, which produced some high-grade ore at the outcrop, was reached by a crosscut from the second level of the Lawson, but proved valueless at depth.¹

Fisher-Eplett (La Rose)

The property was not accessible, and the following information is taken from the annual reports of La Rose.

The claim was first thoroughly trenched and a number of veins were discovered, one of which was a strong vein containing a short shoot of high-grade ore. A shaft was sunk, and at the 200-ft. level four veins were developed of good size, carrying considerable cobalt and nickel with the calcite, but with low silver content. On the 300-ft. level, crosscuts explored the rock for almost the full width of the property to the vicinity of the granite contact. Much drifting was also done. Numerous calcite veins were encountered, but none had any commercial ore. The property was closed and the plant removed in 1914. Much water was encountered in the mine, which made operations expensive.²

CROWN RESERVE

The Crown Reserve Mining Company, Limited, had, during the operation of its Cobalt property, a capitalization of \$2,000,000 in shares of a par value of \$1.00. Recently the capitalization has been increased as a result of its activities in acquiring certain gold properties elsewhere.

The company has produced 20,071,472 ounces of silver from its Cobalt property and has paid \$6,190,849 in dividends. The company ceased active operations at its Cobalt property on January 30th, 1921, except for the hand-sorting of the dump in a small way by a few men.

The cost of producing silver is shown in the following table, which is copied from the annual report of the company for the year ending December 31st, 1919. The cost varied from 7.5 cents an ounce to 94.4 cents an ounce. In 1909 the cost per ounce was 10.31 cents which, in the opinion of the management, was lower than the production cost not only of any other mine in Cobalt, but probably of any other silver mine in the world.³ The company did not own a mill, consequently its ores were treated in certain other plants.

¹Ninth Annual Report, La Rose Consolidated Mines Company, for year 1915, p. 11.

²Eighth Annual Report, La Rose Consolidated Mines Company, for year 1914, p. 11.

³Annual Report of the Crown Reserve Mining Company, Limited, for the year ending December 31st, 1919.

AVERAGE COST OF PRODUCING SILVER TO THE END OF YEAR 1919, CROWN RESERVE

Year	Net production in ounces	Total cost	Price received per oz.	Cost per ounce	Profit per ounce
			cts.	cts.	cts.
1908	1,798,954	\$135,073.56	50.64	7.50	43.13
1909	4,034,325	416,140.90	51.56	10.31	41.25
1910	3,248,196	389,700.48	54.10	11.97	42.13
1911	3,430,902	366,108.53	53.46	10.67	42.79
1912	2,714,766	380,812.96	62.32	14.02	48.30
1913	1,776,678	408,956.13	59.45	23.02	36.43
1914	1,425,320	414,552.40	51.92	28.95	22.97
1915	657,395	344,596.00	52.40	45.01	7.39
1916	274,470	190,266.61	70.40	69.30	1.10
1917	329,670	183,265.97	80.63	55.60	25.03
1918	202,505	191,255.85	97.78	94.44	3.34
1919	196,812	155,804.05	118.80	79.20	39.60
Total . . .	20,089,993	\$3,576,533.44			

The mill and smelter returns to the end of the year 1919 are given in the following table, which is copied from the report to which reference has just been made.

MILL AND SMELTER RETURNS TO END OF 1919, CROWN RESERVE

Year	Gross ounces returns	Gross value	Value
1908	1,798,954	\$910,350.62	\$854,788.89
1909	4,034,325	2,080,156.08	1,895,484.92
1910	3,248,196	1,757,824.27	1,633,716.66
1911	3,430,902	1,833,516.80	1,751,300.21
1912	2,714,766	1,692,060.76	1,638,191.58
1913	1,776,678	1,056,271.86	1,040,117.98
1914	1,425,320	740,092.70	722,873.21
1915	657,395	344,596.00	339,425.81
1916	274,470	193,239.89	191,822.34
1917	329,670	265,839.02	265,155.32
1918	202,505	198,791.35	198,011.35
1919	196,812	233,810.91	233,034.32
Total	20,089,993	\$11,306,550.26	\$10,763,922.59

After a successful and profitable period of production, the Crown Reserve in 1920 reached a stage where the known ore bodies were practically worked out. In the year 1919 the company hoisted and delivered to the Dominion Reduction Company's custom mill at Cobalt 13,755 tons of ore, which averaged 15 ounces of silver per ton. During the year 1920 the output was still further reduced; the year was a disappointing one, there being a deficit of \$72,054.

The company has since acquired a gold property at Larder lake, with the merits of which it is not the province of this report to deal.



Fig. 24—Crown Reserve, Carson vein in the foreground, November, 1907. On the left, the late Sir John Carson after whom the Carson vein was named; centre, Mr. S. W. Cohen; right, Mr. J. G. Ross.

Development

The total mine development to the end of the year 1920 amounted to about eight miles, made up of sinking, raising, drifting, and crosscutting, as shown in the following table.¹

TOTAL MINE DEVELOPMENT, CROWN RESERVE

Development	To 1919	1919	Total
	feet	feet	feet
Sinking and raising.....	4,062	305	4,367
Drifting.....	18,573	1,305	19,878
Cross-cutting.....	15,512	1,088	16,600
Total.....	38,147	2,698	40,845

Development in 1920 amounted to 2,146 lineal feet, making the total development work 42,991 lineal feet, or 8.1 miles.

Structure

The structure of the rocks, and the relationship of the veins to the rocks, is shown in the vertical section facing page 34. This section is based on a general one in Miller's report,² and on a more detailed one kindly furnished by the Crown Reserve Mining Company; the latter, which showed the mine workings, was signed by A. R. Whitman. Certain changes were made in Whitman's section, particularly in reference to the contact between the Keewatin and Cobalt series. The location of the quartz-gabbro, lamprophyre dikes, and chert beds has also been added.

The section is drawn in a north and south direction through the Crown Reserve shaft and the Silver Leaf shaft north of Kerr lake. It will be noted that the central and lower parts of the section consist of Keewatin basalt cut by lamprophyre dikes of Haileyburian age. On top of the Keewatin is the Cobalt series, consisting of conglomerate, greywacké, slate-like greywacké, and quartzite, having a maximum thickness of about 255 feet, the series dipping at gentle angles to the north. At the north end of the section the Nipissing diabase dips at an average angle of about 45° to the north, cutting across the bedding of the Cobalt series. At the south end of the section the diabase dips to the south at an average angle of about 45°. As explained elsewhere in this report, the Nipissing diabase sill in the Kerr lake-Giroux lake area occurs in the form of an elongated dome, the longer axis of which strikes a few degrees north of east. The top of the dome has been eroded, and at the Crown Reserve only the lower limbs remain. It is believed that the diabase was intruded in the form of a dome, and that folding did not cause the sill to take its dome-like shape. Had folding caused the sill to take this form, the sediments of the Cobalt series below the dome would also have been sharply folded. This is not the case, as the sediments dip at gentle angles.

The ore-shoots occur almost entirely in the Cobalt series. They are barren of silver in the diabase, and barren, comparatively speaking, in the underlying Keewatin, although the Carson vein, a very strong one, appears to have produced some silver in the Keewatin. The productive part of the Cobalt

¹Annual Report of the Crown Reserve Mining Company, Limited, for the year ending December 31st, 1919.

²Annual Report, Ont. Bur. of Mines, Vol. XIX, pt. II, 1913, p. 92, section KJ.

series forms a wedge, as shown by the vertical section. On top of this wedge is the Nipissing diabase sill, while below is the Keewatin.

While it is true that the Nipissing diabase has not been productive on the Crown Reserve and Silver Leaf, it should, however, be pointed out that very little work has been done on the veins in the diabase. The most work accomplished was done on vein No. 17 on the 150-ft. level, where the vein was followed into the diabase about 65 feet. It has not yet been demonstrated that the Nipissing diabase is barren in the area north of the Crown Reserve workings.

The Cobalt series has a maximum thickness of about 255 feet; the following table gives the kinds of rock and their approximate thickness, the lowest bed being shown at the base of the column.

THICKNESS OF COBALT SERIES, CROWN RESERVE

Kind of rock	Approximate maximum thickness, feet
Quartzite.....	35 plus
Slate-like greywacké, third bed.....	80
Conglomerate.....	15
Slate-like greywacké, second bed.....	15
Conglomerate.....	55
Slate-like greywacké, first bed.....	15
Conglomerate.....	40
Total.....	255

While the Cobalt series has a total thickness of about 255 feet, it may be pointed out that near the Carson vein it is not much over 100 feet. It will be noted that there are three beds of slate-like greywacké. The lowest one, the first bed, does not come up to the 250-ft. level.

Veins

There are about a dozen productive veins on the property. The company kept a record of the production of these veins, as shown in the table below. This record was published in the annual report of the company for the year ending December 31st, 1919, and was revised for the Ontario Department of Mines by H. J. Stewart.

SILVER PRODUCTION OF VEINS, CROWN RESERVE, TO END OF YEAR 1919

Vein	Production, ounces
Carson.....	9,211,279
Gear.....	2,463,500
Ross.....	2,757,500
Victoria.....	585,500
No. 10.....	549,000
No. 17.....	2,821,000
No. 23.....	89,000
No. 25.....	12,700
No. 19 (Fleming).....	176,780
No. 29 (17).....	988,000
North vein.....	100,000
Miscellaneous.....	62,797
	19,817,056
Dump.....	550,000
Total.....	20,367,056

From the information summarized in the above table, it may be seen that the Carson vein was the most productive on the property, its output of 9,211,279 ounces being almost equal to one-half of the entire production. This yield was obtained above the 200-ft. level. The length of the vein on the Crown Reserve property was only 286 feet, but it extended into the Kerr lake property, where it was known as the Big Chamber. On the Crown Reserve it was explored to a depth of about 500 feet, but it was not productive below the 200-ft. level. Most of this yield appears to have come from the vein where it occurs in the Cobalt series, but there must also have been some production from the vein where it occurs in the Keewatin series, since the vein is stoped between the 200-ft. and the 100-ft. levels and the rock between the 100-ft. and the 200-ft. levels is largely Keewatin. The Cobalt series has a thickness of about 100 feet at the Carson vein, but east of the shaft it is thicker. The contact, however, between the Cobalt series and Keewatin series on the 100-ft. level is a transitional one, and it is therefore only possible to show the approximate line of contact.

Mr. Samuel W. Cohen, who was general manager of the Crown Reserve mine for many years, has kindly given the writer some interesting information regarding the richness and size of the Carson vein. In 1908, when the 100-ft. level of the vein was being opened up, the company produced approximately 900,000 ounces of silver from a drift 200 feet long. In one spot in the drift the vein was 33 inches wide and the ore contained about 12,000 ounces of silver per ton. At one place in the open cut, the vein was 37 inches wide. The actual yield of the whole Carson vein in high-grade alone is over 9,100,000 ounces of silver, produced from a section 286 feet long and averaging 150 feet deep, which includes the lean as well as the rich spots. This gives an average production per square foot of vein area of 217 ounces which, Mr. Cohen believes, is the largest unit production of any silver vein that was ever known, on a section comparable in size with that stated.¹

The vein of next importance is No. 17. It strikes about north-northeast, and has a length of about 500 feet. It has been followed into the diabase for some distance, but has not been productive in that rock. Anyone disposed to take a gamble might be inclined to prospect this vein in the Nipissing diabase.

At the time of our examination of the property in August and September, 1920, the veins were practically worked out; very little information could be obtained by peering into empty stopes and, as the annual reports of the company deal largely with financial matters, the writer was able to obtain little or no information regarding the characteristics of most of the veins. As the table of production shows, the Gear, Ross, Victoria, and No. 10 veins were large producers. The Fleming vein, however, was a disappointment. On the Kerr Lake property this vein was a large producer, but, where explored on the Crown Reserve, it produced only 176,000 ounces of silver.

At the east end of the property on the 200-ft. level a small production came from No. 23 and No. 25 veins, namely, 89,000 ounces and 12,700 ounces of silver, respectively.

The vein known as the North vein produced about 100,000 ounces of silver. This vein was productive in the Keewatin, and has the distinction of having the deepest workings in the mine, namely, 800 feet deep. The company reports that the vein contains gold, assays as high as \$12.00 per ton having been obtained. No native gold was found. The vein may be best examined on the 500-ft. level where it may be seen for 450 feet in the drift. It is a fault vein striking eastward and dipping 70° to the south.

¹Private communication from Samuel W. Cohen, May 4th, 1923.

Pumping of Water out of Kerr Lake

In the year 1913, the water in Kerr lake was pumped out in order to allow the mining of veins which came to the surface under the water of the lake. The operation was carried on jointly by the Crown Reserve and Kerr Lake mining companies.

Pumping was actively begun on the 28th of August, 1913, and in four weeks most of the clear water had been pumped out, lowering the lake 28 feet and leaving silt and mud. Pumping of the silt and mud was continued until November 28th, lowering the lake another 10 feet, making in all a lowering of water, silt, and mud of 38 feet. About 325,000,000 gallons of water, silt, and mud were pumped out. After the clear water was pumped out, it was found that there was an average depth of 25 feet of mud and silt, over the whole lake.

Four single-stage pumps, installed on a 100-ton barge, were used, each pump having a capacity of 1,800 gallons a minute. The pumps were arranged in two units, each unit being directly connected with a 250-horsepower motor.

In 1914 about 600,000,000 gallons of mud and water were pumped. It was necessary to install hydraulic pumps in order to liquify the heavy material consisting of mud and clay; and an additional fresh pump was installed to provide the water. In 1915 drainage of the lake was completed except for a certain quantity of clay in the middle of the lake.¹

The lake has been kept pumped out since that time.

Deep Diamond-Drilling at Crown Reserve

In the summer of 1920, a diamond-drill hole was started on the 500-ft. level of the Crown Reserve mine, the original intention being to continue the drilling to a depth of 2,500 feet² below this. When the hole had reached a depth of 1,500 feet it was decided to stop further drilling, no silver-bearing veins having been encountered. This is the deepest point, approximately 2,000 feet below the surface, at which the rocks at Cobalt have been tapped, either by diamond drill or workings of any description. It is thus of interest, although unfortunately the drill did not discover economic deposits of silver or of any other metal.

The drill hole was started on the 500-ft. level in an east and west drift, 330 feet east of the main crosscut. It was directed at an angle of 70° from the horizontal, the course being south about 40° west. The hole was surveyed at various depths and it was found that its intended direction was maintained to the bottom. As originally planned the depth of the hole was such that at 2,500 feet it would have traversed southwestward across the property and have explored the rocks below the productive silver veins all of which had already been practically mined out.

The writer examined the first 1,050 feet of the core.

Briefly stated, the diamond drill passed through fine-grained basalt of Keewatin age for 197 feet, below which it cut a body of medium-grained quartz-gabbro. The drill remained, for the most part, in the quartz-gabbro at least to a depth of 1,050 feet. It is not known whether the quartz-gabbro is an intrusion of Haileyburian age, or whether it is a coarse-grained variety of Keewatin basalt.

The rocks encountered by the drill have no economic significance as far as the further discovery of silver ore is concerned. As a matter of fact the deeper the drill penetrated the farther it retreated from the source of the ore, the source

¹Annual Reports, Crown Reserve Mining Company, Limited, 1913, 1914, 1915.

²Annual Report of the Crown Reserve Mining Company, Limited, for year 1920.

of the ore being the Nipissing diabase. One object which the Crown Reserve management had in mind, when the drilling of the hole was proposed, was to explore for a second sill of diabase below the Nipissing diabase sill. It may be added, however, that the core showed no evidence of a second sill of diabase.

A description of the rocks encountered by the drill is given more fully in following paragraphs. In connection with the description, about forty thin rock sections of the core were examined under the microscope.

The first 188 feet of the core consist of fine-grained basalt of Keewatin age, showing under the microscope a network of plagioclase rods which are set in a ground-mass of secondary minerals such as chlorite. Here and there are specks and tiny veinlets of iron pyrites, pyrrhotite, and copper pyrites. Veinlets and stringers, fractions of an inch in width, of white calcite occur every few feet.

At a depth of 179 feet 5 inches, the drill passed into a brecciated zone of Keewatin basalt, this zone consisting of fragments of basalt, round and angular, fractions of an inch or more in diameter. The brecciated zone continues to a depth of 200 feet, the last three feet consisting of brecciated quartz-gabbro. Between 180 and 185 feet about three-quarters of the core was lost.

At 197 feet the drill entered a body of quartz-gabbro. It continued to cut this rock to a depth of at least 1,050 feet, with the exception of a few places in which it intersected fine-grained rocks.

Thin sections of the quartz-gabbro from many parts of the core were examined under the microscope, and the rock was found to consist mainly of hornblende and feldspar. There are also microscopic intergrowths of quartz and feldspar, owing to the presence of which the rock has been named quartz-gabbro, Ilmenite altered to secondary material is found. The rock is much more weathered than the Nipissing diabase, and when both rocks are studied under the microscope and compared with each other, there is no difficulty for anyone who is familiar with the rocks at Cobalt to distinguish the two types. The hornblende in the quartz-gabbro is sometimes altered to chlorite, while the feldspar is badly decomposed to secondary minerals. In the Nipissing diabase, on the other hand, the pyroxene and feldspar are generally fresh.

In a few places between 197 feet and 1,050 feet, the rock becomes fine-grained, and it was not determined whether the drill passed out of the quartz-gabbro intrusion or whether the quartz-gabbro became finer in grain.

The quartz-gabbro becomes somewhat acid in places. For instance, the thin section from a depth of 299 feet showed an unusual quantity of quartz; possibly this part of the core might be named a grano-diorite.

Between 420 and 425 feet, the rock is rather fine-grained, although a thin section examined under the microscope from a depth of 422 feet showed it to be a quartz-gabbro.

Between 439 and 450 feet, the rock is fine in grain. A thin section at 439 feet 6 inches shows the rock to be a different type from either the quartz-gabbro or the common basalt of Keewatin age at Cobalt. It consists of fine needles of hornblende set in a feldspathic matrix. No quartz was noted. It is difficult to say whether the drill at this depth, i.e., between 439 feet and 450 feet, passed out of the gabbro into an adjacent rock, or whether it passed through a fine-grained, border phase of the gabbro.

Between 450 feet and 451 feet 6 inches, the core has a banded texture, about a dozen bands, alternately fine and coarse grained, occurring. A thin section at a depth of 451 feet showed irregular grains of feldspar set in a matrix of chloritic material. Cutting across the section is a band consisting mostly of carbonate.

The rock between 451 feet and 6 inches and 507 feet is fine to medium in grain, and is banded in places. The banded structure is suggestive of sediments, although a thin section at a depth of 479 feet 8 inches gave no hint of a sedimentary origin, the rock consisting of fresh plagioclase feldspar and a few grains of quartz set in a matrix of chlorite and a few needles of hornblende. A thin section from 499 feet 6 inches also shows banding, due to alternating bands of fine and coarse grains of quartz and feldspar; whether this is the banding of acidic vein material or of sediments was not determined.

Between 507 feet and 1,050 feet, thin sections show that the drill passed through quartz-gabbro, except at 850 feet, at which point the rock appears to be a lamprophyre.

The quartz-gabbro from the point at which it was first encountered, that is at 197 feet, down to a depth of 1,050 feet is cut by hundreds of calcite veinlets and stringers usually fractions of an inch in diameter.

In a few places sulphides and arsenides were met with. At a depth of 39 feet, the drill cut 8 inches of calcite with which occurred some smaltite. At 178 feet, a three-inch vein of calcite containing a little zinc blende and galena was encountered by the drill. Between 178 feet and 179 feet 5 inches, there is a stringer of calcite three-eighths of an inch wide carrying zinc blende and galena. At 181 feet, there is a two-inch vein of calcite carrying zinc blende.

The plan of the 500-ft. level of the Crown Reserve incorrectly shows the drill hole to have a depth of 1,800 feet.

The chemical analysis of the quartz-gabbro, shown in the following table, was made by W. K. McNeill, Provincial Assayer. The sample was taken from the diamond-drill core at a depth of 1,000 feet below the 500-ft. level.

ANALYSIS OF QUARTZ-GABBRO, CROWN RESERVE

	Per cent.
Si O ₂	45.82
Al ₂ O ₃	17.71
Fe ₂ O ₃	0.14
Fe O	12.60
Ca O	8.66
Mg O	4.21
Na ₂ O	2.33
K ₂ O	0.80
C O ₂	3.37
H ₂ O (combined)	4.66
Total	100.30

Description of Mine Workings

550-ft., 700-ft., and 800-ft. Levels.—These levels are reached from a winze from the 500-ft. level. The deepest workings in the Crown Reserve are on the north vein, which was discovered in 1912 and which produced about 100,000 ounces of silver. The vein, which is at the north end of the property, is not an important one, but is of interest on account of the depth to which it was worked. The workings on the vein are somewhat isolated from the more productive part of the property and may be considered almost as a separate mine. On the lower levels the company reported that gold was found in the vein, assays as high as \$12 per ton having been obtained. The discovery of this gold has proved to be of no economic significance.

The vein was discovered when the crosscut on the 500-ft. level was being driven between the main winze from the Crown Reserve shaft to the Silver

Leaf north shaft as shown on the coloured vertical section facing page 34. The vein strikes eastward and dips about 70° to the south. It varies from a mere crack to about 18 inches in width, and averages probably 3 or 4 inches in width. It consists largely of calcite, but contains also some quartz and a little smaltite. The silver occurred in irregular patches, but the quantity was small; and the writer was given to understand that it scarcely paid to work it. The vein occurs in a fissure, which in places shows a fault breccia as wide as 12 inches and a gouge about an inch wide; but for the most part the gouge and breccia are less than this.

The vein occurs largely in the quartz-gabbro, but it also appears to extend up and into the Cobalt series on the 300-ft. level.

On the 800-ft. level, the rock is largely quartz-gabbro; at the eastern part of the level the rock is fine to medium in grain, and 15 feet west of the east end of the drift the rock is basalt. The vein on the 800-ft. level averages about 4 inches in width, but varies from a crack to 18 inches.

The rock in the winze between the 700-ft. and 800-ft. levels appears to be largely quartz-gabbro.

On the 700-ft. level, part of the rock is quartz-gabbro, two thin sections having been examined under the microscope. The vein on the 700-ft. level varies from a mere crack to 12 inches in width; it averages some 2 or 3 inches. On this level a raise was driven, and at a height of 55 feet above the level the vein was about 6 inches wide at one place where it contained a little high-grade silver ore and smaltite.

Near the east end of the 700-ft. level there is a fault consisting of crushed rock; it was encountered in two places, in the crosscut and about 60 feet west of the east end of the drift. This fault has about the same strike and dip as the prominent fault on the 500-ft. level described below. The mine captain, Mr. Martin, stated that the silver on this level, the 700-ft., appeared to be concentrated at the junction of the fault and the vein.

In the winze between the 700-ft. and 550-ft. levels, there is a fine-grained dike 6 inches wide cutting the quartz-gabbro.

In the winze between the 550-ft. level and the 500-ft. level, the rock is quartz-gabbro and lamprophyre.

500-ft. Level.—The level is reached from a winze on the 300-ft. level about 40 feet north of the Crown Reserve shaft. The Silver Leaf north shaft also goes down to this level, but this shaft has not been in use for some years.

There are two main veins on this level, the Carson and the North veins. The former was drifted on for 200 feet, and, while the vein was continuous for this distance, no silver of economic consequence was encountered.

The North vein strikes eastward and dips at 70° to the south. It contained a few rich patches of silver ore, and although the vein produced, as already stated, 100,000 ounces of silver, it was not profitable. The vein occurs in a fault and varies in width from 2 to 12 inches. The evidence of faulting, namely, the fault breccia and gouge, is not marked on this level, but in the lower workings the faulting is more marked, although the displacement was not worked out.

In the main crosscut about 430 feet south of the Silver Leaf shaft, there is a well-defined fault dipping steeply southeastward. The fault consists of a zone of crushed rock about 2 feet wide, and a gouge up to 2 inches wide. Iron pyrites and other sulphides occur in it. The fault strikes in a northeastward direction. A fault, which appears to be a continuation of this fault, is met with in the east and west drift which follows the North vein. This fault,

which is about 250 feet east of the crosscut, intersects the North vein at a gentle angle. The age relationship of the fault to the North vein is a debatable question. It is not clear to the writer whether the fault is older or younger than the vein. The displacement of the fault was not determined.

The rocks on the 500-ft. level are Keewatin and Haileyburian in age. The Keewatin consists of a fine-grained basaltic rock, together with two beds, less than 5 feet thick, of black, fine-grained siliceous carbonaceous "iron formation" carrying iron pyrites. These two beds occur about 45 and 100 feet, respectively, north of the winze at the south end of the main crosscut. A mica-lamprophyre dike of Haileyburian age cuts the "iron formation" bed nearest the winze; this dike is 5 or 6 feet wide and dips about 35° to the northwest. Other lamprophyres are found on this level. The north half of the main crosscut is composed mostly of quartz-gabbro, medium in grain. It is supposed that this quartz-gabbro is of Haileyburian age, although there is no definite proof as to its exact age, except that it is older than the lamprophyre dikes. The gabbro is first seen in the crosscut about 133 feet south of the "North" vein, and it continues north to the Silver Leaf shaft, except where it is cut by a mica-lamprophyre dike. The contact between the quartz-gabbro and Keewatin is not sharply defined. This quartz-gabbro has the same composition as the quartz-gabbro which was encountered in the diamond-drill hole on the 500-ft. level.

450-ft. Level.—The level is mainly in quartz-gabbro together with lamprophyre.

300-ft. Level.—The Carson vein has been drifted on for about 250 feet and found to be 2 to 6 inches wide of calcite and some smaltite. The silver content was not of commercial grade. The vein was further explored by a winze, following the vein, from this level to the 500-ft. level.

The north part of the 300-ft. level, which is distinct from that part on which the Carson vein occurs, is reached by a winze from the 200-ft. level. In this part of the level there is a shallow basin of the Cobalt series resting on the greenstones, the basin striking eastward. The North vein, which roughly parallels the basin, has been stoped, but it has not been followed upwards into the overlying Nipissing diabase. Indeed, the North vein has not been recognized on the 200-ft. level. The vein occurs in a fault showing fault breccia and gouge as wide as one or two feet in places.

No. 17 vein was followed from the 200-ft. to the 300-ft. level by a winze, and on the plan of the 300-ft. level the vein is shown at the winze, striking a little west of north. Vein No. 17 was faulted about 2 feet by the North vein.

A bed of slate-like greywacké at least 7 feet thick is exposed in the stope on the north vein; it is also met with at the west end of the level.

250-ft. Level.—The level is reached by a winze from the 200-ft. level. The contact between the Keewatin and Cobalt series shows that the Keewatin forms a hill on which the Cobalt series is deposited.

200-ft. Level.—This is the most extensive level in the mine, its workings intersecting the rock from the east almost to the west boundary. The exploration of the eastern half of the level proved disappointing. It was hoped that the Fleming vein, for instance, would be a large producer, since on the Kerr Lake mine it was a very important one. As already stated it only produced 176,780 ounces of silver on the Crown Reserve.

At the contact between the Nipissing diabase and the Cobalt series, north of the winze on vein No. 17, there has been faulting. At the winze the bed of slate-like greywacké dips northward at the gentle angle of 4° , but at the contact the bed dips much more steeply, suggesting that the diabase was faulted down, or

that the beds were bent down during the intrusion of the diabase, and later faulting along the contact caused a farther bending down of the beds. Elsewhere in this report it is suggested that the diabase was intruded from the southeast to the northwest. At this point in the Crown Reserve, therefore, the diabase was intruded downward across the bedding of the Cobalt series. It cut its way downwards for an unknown distance, then flattened out, and finally rose again, emerging along the Nipissing and O'Brien properties, where it was exposed by erosion.

In the main crosscut north from the Crown Reserve shaft, the diabase was penetrated at the north end of the drift. There is no faulting at the contact, the fine-grained diabase being frozen against the slate-like greywacké, the contact dipping 48° to the north. North of the contact about 22 feet a fault does occur; this fault may be the same one that occurs at the diabase contact north of the winze on vein No. 17.

In the eastern part of the level, our plan shows a fault dipping 20° to 30° to the north. This fault is in the long crosscut, and it occurs in the Cobalt series near the diabase contact.

Judging from these three occurrences it would appear that a fault follows, in a general way, the contact between the Nipissing diabase and the Cobalt series. The work at the Crown Reserve was done in 1920, and at that time the Ontario Department of Mines was not paying the same attention to faults as was later done in 1921, 1922, and 1923, consequently the faults on the Crown Reserve have not been mapped as they should be.

On the 200-ft. level there is also a fault which roughly follows the contact between the Keewatin and Cobalt series. The location of this fault is shown in three crosscuts north of the Crown Reserve shaft. Between the 200-ft. and the 250-ft. levels, there is a fault dipping at about 30° . In places this fault is banded. It contains nodules of iron pyrites.

150-ft. Level.—This level is of interest on account of the fact that vein No. 17 was followed into the Nipissing diabase for about 65 feet, and was found to be unproductive. Vein No. 17 was the second largest producer on the property.

The outlines of the second and third beds of slate-like greywacké are shown. These beds are in places almost horizontal, and in other places dip as high as 19° .

130-ft. Level.—The level is a small one, mainly in veins around the shaft. It is mostly in the Keewatin. The contact between the Keewatin and Cobalt series is indicated by a dotted line.

100-ft. Level.—Difficulty was met with in determining the contact between the Keewatin and Cobalt series at the Carson vein. About a dozen samples of the rock were examined under the microscope, and the Keewatin basalt was found to be much decomposed at the contact. In fact, the contact is the transitional type in which the unaltered Keewatin basalt passes gradually upwards into altered basalt, thence into a basal conglomerate of the Cobalt series in which the fragments are largely Keewatin basalt, and finally into a typical conglomerate of the Cobalt series. Under these conditions it is difficult to decide where to place the line of contact. It might be placed at the unaltered basalt, or at the point where the typical conglomerate is developed. We have chosen a line midway between these two extremes, but we will not quarrel with those who are disposed to move the line a few feet to the south.

From one point of view the determination of the contact is important. For instance, on our plans the contact is shown about at the Carson vein, although east of the shaft the contact is below the 100-ft. level at the Carson vein. As this vein has been stoped down to the 200-ft. level, it would seem that some

silver must have been obtained from the vein where it occurs in the Keewatin. According to Mr. Samuel D. Cohen, the vein was productive to an average depth of 150 feet.

The north part of the level is largely in a bed of slate-like greywacké, which dips for the most part at angles of 10° or 12° northward.

50-ft. Level.—The Carson vein at the west end splits into two branches which continue into the Silver Leaf a short distance. On the Crown Reserve the barren part of the vein may still be seen, showing in one place 10 inches of calcite.

McKINLEY-DARRAGH-SAVAGE

The McKinley-Darragh-Savage Mines of Cobalt, Limited, has a capital of \$2,500,000 in shares of a par value of \$1 each. Of this amount, \$2,247,692 had been issued. To the end of the year 1922, the company had produced 19,941,726 ounces of silver, including the Savage mine, and had paid \$5,955,592 in dividends. The company operates the McKinley-Darragh and the Savage mines, the former having produced most of the ore.

The cost of producing silver during the year 1922 was 54 cents an ounce, or \$6.25 per ton of ore. The details of these costs are shown in the following table.

COST OF PRODUCING SILVER AT McKINLEY-DARRAGH¹ IN YEAR 1922

Operations	Total amounts	Per ton of ore mined	Per ounce recovered
Insurance, taxes, administration, etc.	\$22,032.80	\$0.851	\$0.0742
General charges at Cobalt.	8,644.73	0.334	0.0291
Mining.	44,843.51	1.732	0.1510
Milling.	44,247.94	1.709	0.1490
Sampling and assaying at Cobalt.	2,412.04	0.093	0.0081
Bagging and shipping.	1,910.09	0.074	0.0064
Operating camps.	682.67	0.026	0.0023
Surface work, roads, etc.	1,570.17	0.061	0.0053
Alterations to plant.	3,531.55	0.136	0.0119
Prospecting.	4.32		
Surface dumps.	199.50	0.008	0.0007
Savage.	1,310.90	0.051	0.0044
Production costs.	\$131,390.22	\$5.075	\$0.4424
Marketing costs.	\$22,243.68		
Less cobalt and copper.	7,609.02		
	14,634.66	0.565	0.0492
Shut down costs.	15,915.93	0.615	0.0536
Total costs.	\$161,940.81	\$6.255	\$0.5452

¹Annual Report, McKinley-Darragh-Savage Mines for year 1922.

The company has compiled the table printed below showing the costs and profits of producing silver from the years 1906 to 1922,¹ inclusive.

COSTS AND PROFITS PER OUNCE OF SILVER RECOVERED, MCKINLEY-DARRAGH

Year	Average price received	Total costs	Net profits per ounce
1906-7.....	\$0.59	\$0.2614	\$0.3286
1908.....	0.52	0.2341	0.2859
1909.....	0.5131	0.2263	0.2868
1910.....	0.5405	0.1705	0.3700
1911.....	0.5416	0.19479	0.34681
1912.....	0.6166	0.1859	0.4307
1913.....	0.5919	0.2233	0.3686
1914.....	0.54385	0.31325	0.2306
1915.....	0.50785	0.28710	0.22075
1916.....	0.67364	0.40730	0.26634
1917.....	0.8320	0.5709	0.2611
1918.....	0.99724	0.6842	0.31304
1919.....	1.1065	0.7193	0.3872
1920.....	0.8060	0.8562	Loss 0.0502
1922.....	0.64995	0.5452	0.10475

The property was closed at the end of the year 1920, and opened again on May 15th, 1922; six weeks later a normal tonnage was being hoisted. During the year 1922 the mill treated 25,848 tons of ore, the mill-heads of which assayed 12.1 ounces of silver per ton.

There are 15.2 miles of underground workings including drifts, crosscuts, raises, winzes, and shafts. The table below, giving a record of the work done, was published in the company's annual report for the year 1922.

EXTENT OF MINING OPERATIONS, MCKINLEY-DARRAGH MINES

Year	Shafts	Drifts	Cross-cuts	Stopes	Raises	Winzes	Station	Trenches
	feet	feet	feet	tons	feet	feet	cu. yds.	feet
1906-7-8.....	966	4,190	2,971	4,181	301	175	.....	4,000
1909.....	200	2,007	1,499	7,126	415	81	.....	10,900
1910.....	106	2,437	2,417	18,084	252	60	.....	150
1911.....	14	3,256	3,757	36,261	824	93	.....	.....
1912.....	85	4,706.5	3,164.5	42,592	632.5	167.5	.....	.....
1913.....	.....	4,260	4,088	43,741	857	105	.....	.....
1914.....	.....	1,848	4,383.5	39,855	838	170.5	.....	.....
1915.....	58.5	2,527.5	1,431	50,753	443	78	.....	.....
1916.....	3.5	2,444	1,808.5	39,340	738.5	279.5	238	.....
1917.....	14.5	2,408	1,876.5	46,712	374.5	12	240	.....
1918.....	.....	4,370	3,433	34,255	441	18	.....	.....
1919.....	1	1,340	1,241	27,218	556.5	26	.....	.....
1920.....	.....	1,084	1,110.5	38,990	534.5	.....	.....	.....
1922.....	.....	113.5	94.5	16,752	112.5	.....	.....	.....
Total.....	1,447.5	36,991.5	33,275	445,860	7,320	1,265.5	478	15,050

In the matter of ore reserves at the end of the year 1922, the company reported that there were approximately 20,000 tons of broken ore, and "a considerable tonnage of unbroken ore to be mined."²

¹Annual Report, McKinley-Darragh-Savage Mines for year 1922.

²Annual Report, McKinley-Darragh-Savage Mines, 1922, p. 4.

The table below, showing the yearly shipments from 1906 to 1922, was compiled by the company in the annual report for the year 1922.

OUNCES OF SILVER SHIPPED FROM THE MCKINLEY-DARRAGH MINES, 1906 TO 1922

Years 1906-7.....	675,656
Year 1908.....	738,212
" 1909.....	1,324,704
" 1910.....	2,621,888
" 1911.....	2,569,654
" 1912.....	2,704,868
" 1913.....	2,228,497
" 1914.....	1,260,046
" 1915.....	1,060,136
" 1916.....	1,055,996
" 1917.....	1,020,545
" 1918.....	886,398
" 1919.....	760,482
" 1920.....	613,483
" 1922.....	254,307
Total to January 1st, 1923.....	19,774,872

The known veins in the McKinley-Darragh were nearly mined out at the time of our examination in 1921, so that very little first-hand information could be obtained regarding them. They form a complex network, particularly well developed on the 150-ft. level. None of the veins extend from the footwall into the hanging-wall of the Cobalt lake fault. One of them on the 400-ft. level is stoped up to the fault, but the writer was informed that the silver content gradually disappeared before reaching the fault. This vein did not extend to the surface.

On the 350-ft. level there is a vein in the Cobalt lake fault which follows the fault for a distance and then gradually leaves it and passes into the footwall. This vein had an ore-shoot which produced approximately 500,000 ounces of silver.

The veins in the McKinley-Darragh are limited on the southeast by the Cobalt lake fault, and as to depth by the Keewatin floor.

In our examination of the mine, we were struck by the fact that there are scarcely any veins now to be seen on the various levels; they have been largely mined with the exception of mill-rock. This appears to show that practically all the veins on the property were productive. These veins are different in this respect from many in the Beaver and Temiskaming mines. At the Beaver and Temiskaming, barren veins are to be seen in some of the drifts; they have in some cases been followed for hundreds of feet, and have been found to be barren of silver, or to have short ore-shoots.

In the annual report of the company for the year 1910, there is an excellent vertical section showing the structural features of the mine. The section shows that the rocks northwest of the Cobalt lake fault have been severely faulted, though the displacement is not nearly so great as is the displacement in the Cobalt lake fault. Veins are shown by the section to occur in these faults. Owing to the nearly worked-out condition of the property at the time of our examination, we were not able to confirm or disprove the presence of these faults in which the veins are shown to occur.

There are two beds of slate-like greywacké, the outlines of which are shown on the vertical section just referred to. Where these beds abut against the Cobalt lake fault, they are bent upwards by the reverse movement of the fault.

Some trouble was met with in mapping the slate-like greywacké on account of the fact that in places it passes gradually into the conglomerate, which makes

it difficult to decide as to where the contact line should be drawn on the level plans. An attempt was made, however, to show these beds separately on the plans because of their economic importance. Their importance is due to the fact that where certain veins pass through them, the mill-rock is reported to be of better grade than the mill-rock in the conglomerate. The lower bed of slate-like greywacké rests in places directly on the Keewatin floor, but more generally it is from a few feet to 30 or 40 feet above the Keewatin floor, with conglomerate between the floor and the slate-like greywacké.

If the vertical section facing page 12 be examined by the reader, it will be noted that at the bottom of the mine the conglomerate is over 100 feet thick. Above the conglomerate is the lower bed of slate-like greywacké. On the 250-ft. level this lower bed of slate-like greywacké rests in places, as already stated, directly on the Keewatin floor. It is thus evident that the trough in the Keewatin floor, which occurs below the bottom of Cobalt lake, was first filled with conglomerate to a depth of at least 100 feet. Later on the lower bed of slate-like greywacké was laid down; in the middle of the trough the slate-like greywacké rests on the conglomerate, but higher up the sides of the trough it rests, in places, directly on the Keewatin. A little reflection will make it apparent that this trough in the Keewatin is therefore essentially due to erosion. No doubt the trough was accentuated by folding which took place along the axis of the Cobalt lake fault. This folding is certainly proved by the upturned beds of the slate-like greywacké.

The Cobalt lake fault, which dips 50° to 60° to the southeast, is a reverse one with a displacement of about 550 feet. At La Rose mine the displacement is less, about 275 feet. One might therefore fairly assume from this that the amount of displacement becomes less towards the north.

The writer had a better opportunity to study the Cobalt lake fault at the McKinley-Darragh than at any other property in the area, and it may be described in some detail.

The entire hanging-wall is Keewatin, and the footwall is Cobalt series down to the bottom level. The fault may be said to consist of two parts, first the gouge which is persistent throughout, and second the fault breccia. The fault breccia occurs on each side of the gouge, although most of it is below the gouge in the more easily crushed conglomerate and greywacké of the Cobalt series. The gouge consists of what the miners call a "mud seam", and it varies in width from a quarter or half an inch to an inch or two. It consists of a soft, plastic, clay-like material. The fault breccia consists of crushed and broken rock with some clay and it varies in width from a few feet to 15 or 20 feet or more. The crushed rock becomes less and less crushed as the distance from the gouge becomes greater. It is along the gouge that the movement has taken place. The gouge offered a smooth, greasy plane, along which the movement between hanging-wall and footwall occurred. In the fault in many places there is a calcite vein which reaches an extreme width of 3 or 4 feet, and in which an important ore-shoot of silver was found. This ore-shoot is described below.

An interesting feature of the exploration campaign at the McKinley-Darragh mine is the persistence with which the Cobalt lake fault has been explored. It has been systematically developed on six levels for a total distance of between 6,000 to 7,000 feet. No doubt the reason for so much work along the fault was the discovery of the valuable ore-shoot mentioned above, which was found in the fault between the 350-ft. and 300-ft. levels. This ore-shoot partly follows the fault, and then gradually leaves it and runs into the conglomerate; at its southwest end the vein is about 3 or 4 feet or more northwest

of the gouge. As already stated, according to information received from the management, this ore-shoot produced approximately 500,000 ounces of silver.

From the plans of the McKinley-Darragh levels, and from the vertical section facing page 12, it will be seen that on lower and lower levels the width of the productive formation, the Cobalt series, becomes less and less, until on the 400-ft. level it has an average width of only 135 feet; on the 450-ft. level it is reported to be more narrow still.

The Keewatin consists mainly of basalt, although there is some Keewatin "iron formation." The contact between the Keewatin basalt and the Cobalt series is generally transitional, but the contact between the "iron formation" and the Cobalt series is often sharp and well defined.

On the surface of the property a small remnant of the bottom of the Nipissing diabase sill was found in the railway cutting. This patch is about 15 feet wide and at least 40 feet long, being covered with drift towards the Cobalt lake fault. It is interesting to find this patch here. It corresponds structurally to that at La Rose, but at La Rose it is much larger.

Description of McKinley-Darragh Workings

450-ft. Level.—This level was not accessible; the following information was obtained from the company. A vertical winze was sunk from the 400-ft. to the 450-ft. level, and a crosscut was run southeast about 75 feet where it encountered the Cobalt lake fault. The fault was then drifted on about 200 feet to the northeast, and about 125 feet to the southwest. Near the southwest end of the drift, there is an inclined raise along the fault up to the 400-ft. The Keewatin was encountered in the lower part of the winze. The crosscut from the winze to the fault was said to be in Keewatin for some distance southeast of the winze, after which it entered the Cobalt series and remained in this series up to the Cobalt lake fault.

400-ft. Level.—The Cobalt lake fault has been explored by a drift on this level for about 900 feet. A calcite vein occurs in places in the fault; the vein is 4 feet wide at one point, but contains no silver. In many places in the gouge and in the crushed rock beside the gouge there is cobalt bloom, and in one place some smaltite. Here and there much rusty material occurs which may be altered iron pyrites. For long distances, 50 to 100 feet, there is no calcite vein in the fault. Towards the northeast end, the fault contains much graphitic material. The rock is very badly crushed at this end, and the cost of mining the drift was therefore low.

In a number of places in the mine, there are veins which run towards the Cobalt lake fault at right angles, such as vein No. 70 on the 400-ft. level, east of the shaft. The vein became weaker as it approached the fault, and it is reported that the silver content disappeared before it reached the gouge of the fault. An interesting feature of this vein is that it is a blind one, and does not reach the surface. It is thus limited by the Keewatin floor below, by the Cobalt lake fault on the southeast, and vertically by the fact that it pinches out.

350-ft. Level.—The most interesting feature of this level was the occurrence of an ore-shoot, the northeast end of which was in the Cobalt lake fault; that is to say, the vein rested directly against the gouge at the northeast end, but towards the southwest the vein gradually left the gouge until, at the southwest end of the drift, it was 3 or 4 feet or more northwest of the gouge. All of the silver-bearing portion of this vein has been mined except a small pillar about 3 or 4 feet square. It is in this pillar that the vein may still be seen resting directly against the gouge of the fault. This vein is about 2 or 3 inches wide

in the pillar and consists of smaltite, niccolite, native silver, and calcite. At the southwest end of the vein, the unproductive part may still be seen in the back of the stope about 15 feet or so above the floor. The vein here consists of smaltite and calcite, and in places there are two or more parallel veins. Fig. 2 is a photograph of the stope, showing the hanging-wall of the Cobalt lake fault.

The productive part of the vein extended 20 feet below the level and rose a maximum 50 feet above the level, a total vertical distance of 70 feet. The length of the ore-shoot was about 275 feet. The width of the vein was a few inches, but it was said to be in one place as much as 5 feet in width, 2 feet of which was high-grade ore. This rich part was about 12 feet long. The company reported that the ore-shoot yielded about 500,000 ounces of silver.

Southwest of this ore-shoot a calcite vein in the Cobalt lake fault attains a width of 2 feet, and it carries in places some iron pyrites and other sulphides.

About 270 feet southwest of the main shaft there is a vein-system striking southeast towards the Cobalt lake fault. The stope on this vein-system comes up to the fault, but we were not able to find out whether or not the ore-shoot in the vein extended as far as the fault.

At 185 feet from the northeast end of the Cobalt lake fault, there is an almost vertical fault running into the Cobalt lake fault at an angle of about 30° .

At the southwest end of the property, there is a vein in the Keewatin series which is said to contain good mill-rock. The vein extends up to the 300-ft. level.

300-ft. Level.—This level has a drift along the Cobalt lake fault for almost a quarter of a mile. An interesting feature of the fault is that at the southwest end there are horizontal striations in the walls of the gouge, indicating some horizontal movement.

At the southwest end of the mine, a bed of slate-like greywacké abuts against the Cobalt lake fault, and the beds have been thrust up in the manner commonly seen in reverse faults. The bed begins to tilt up 30 feet from the fault. Near the fault the bed dips at 50° to 70° to the northwest.

This level is characterized by a bed of slate-like greywacké, finely bedded and having a thickness of from 10 to 25 feet. It does not occur on the lower levels. The bed is generally separated from the Keewatin by a bed of conglomerate and greywacké from 5 to 15 or 20 feet thick.

In the northeast part of the Cobalt lake fault, cobalt bloom occurs almost continuously along the gouge for about 300 feet. At one place some smaltite was found in the gouge, and there is a stope in this part of the vein in which a small quantity of silver was found. The vein is clearly younger than the fault.

250-ft. Level.—A feature of this level is the manner in which the bed of slate-like greywacké for a thickness of about 8 feet has been mined in a manner similar to that in which a gently dipping coal seam is mined. The bed dips at an angle of about 15° . The mining of this bed of slate-like conglomerate is due to the peculiar manner in which the "Lake" vein occurs. A glance at Fig. 25 will explain its character. The Lake vein descends vertically to the slate-like greywacké; then, by a series of "steps," passes through the bed. The slate bed was impregnated with native silver, and it was thus possible to mine about 8 feet of the bed. The vein in the Seneca was affected in a similar manner when it encountered a bed of slate-like greywacké (Fig. 32).

There is a crosscut about 800 feet long running southeast from the shaft and intersecting vein No. 7, the Kendall. The crosscut intersected Keewatin basal southeast of the Cobalt lake fault. The Keewatin was cut by coarse-grained lamprophyre dikes. The Kendall vein on this level is 7 to 8 inches wide of calcite.

200-ft. Level.—An interesting feature is the occurrence of a fault similar to the "contact" fault on the Coniagas. It occurs in the conglomerate a few feet above the Keewatin, and we were able to trace it for 600 feet. It is most prominent at the southwest end of the mine, and becomes weaker towards the northeast. This fault was also noted on the 250-ft. level.

150-ft. Level.—The contact between the Keewatin and Cobalt series on this level is much more irregular than on any lower level. The contact shows the Keewatin floor to consist of two prominent hills with intervening troughs. This irregularity is due to erosion in the Keewatin before the Cobalt series was laid down. If the troughs were due to folding after the Cobalt series was laid down, the Cobalt series would also be folded. Such minor folding as there is does not conform to the Keewatin troughs.

This level has more development work done on it than has any other level, and it is the most productive.

An attempt has been made to show the outlines of two beds of slate-like greywacké. It was found to be an unsatisfactory piece of mapping, but, in

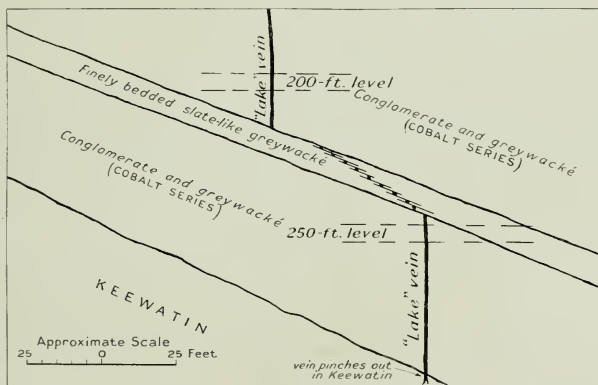


Fig. 25—Sketch illustrating what happens to the "Lake" vein, McKinley-Darragh mine, when it passes from conglomerate and greywacké into a bed of finely-bedded, slate-like greywacké.

view of the structural importance of the beds, it was thought advisable to map them as best we could in the time at our disposal. The upper bed is thicker than the lower. Where the upper bed abuts against the Cobalt lake fault, the bed is tilted up at angles as high as 50° or 60° .

At the northeast end of the Cobalt lake fault, there is a barren calcite vein about an inch wide containing cobalt bloom. The vein strikes towards the Cobalt lake fault at right angles. Where it enters the fault it splits into three or four small stringers. These stringers gradually change their strike and, in place of running directly into the gouge at right angles, they gradually turn and finally follow the gouge itself. It would appear that this vein is a subordinate fracture from the Cobalt lake fault.

110-ft. Level.—The Keewatin has not been encountered on this level, nor do the workings extend to the southeast far enough to intersect the Cobalt lake fault. There is much slate-like greywacké on the level, but, owing to the fact

that many of the workings are inaccessible, it was not found practicable to map it. The slate-like greywacké is resting at gentle angles, in places 5° to 10° .

75-ft. Level.—An interesting feature of this level is the occurrence of a silver-bearing vein in the hanging wall of the Cobalt lake fault. The vein is about 4 feet to the southeast of the fault. It is said to have produced about \$25,000 in silver. The vein may still be seen in the back of the small stope where it consists of 3 or 4 inches of smaltite and calcite, together with a little niccolite.

60-ft. Level.—The workings on this level are not extensive. The rock is conglomerate of the Cobalt series. What is known as the "first swamp" vein occurs on the level. The vein is now stoped out.

Kendall Vein.—No. 7 vein, the Kendall, on the 60-ft. level of No. 7 shaft, occurs at the southeast part of the property. The vein is known as the Kendall vein on the Nipissing, on which property most of the ore was obtained. This is due to the fact that the conglomerate on the McKinley where the vein occurs is but 14 feet deep in the shaft. While the vein in the Keewatin is a strong vein, 1 to 12 inches wide, of calcite and a little quartz, and has been explored for 250 feet in depth, it was not commercially productive in the Keewatin rocks, although some rich patches were found. One of these rich patches in the vein may still be seen on the 60-ft. level.

The No. 7 vein was worked from the No. 7 shaft from the 60-ft. and 100-ft. levels. A long crosscut from the 250-ft. level of the main shaft was driven about 800 feet southeast and intersected this vein, where it was found to be a strong one consisting of 7 to 8 inches of calcite. In the Cobalt series the vein was about vertical, but on entering the Keewatin it dips southward at a steep angle. Where we observed the vein in the Keewatin it occurs in a minor fault.

SAVAGE

The Savage mine is owned by the McKinley-Darragh-Savage Mines of Cobalt, Limited.

The vein-system consists of a number of parallel veins striking north-eastward, as shown on the plans. The ore-shoots are confined to the southeastern half of the property where the conglomerate is shallow. The veins do not contain ore in the Keewatin nor does the ore as a general rule extend to the surface. It is probable that the Keewatin floor influenced the deposition of the silver ore-shoots, as it has elsewhere in the Cobalt area. The chimney-like form of some of the ore-shoots is a feature of the Savage ore bodies.

A characteristic of the ore bodies is that the silver has not extended into the wall-rock as far as it has, for instance, at the Coniagas, McKinley-Darragh, or other properties. Hence the stopes are narrow, ordinarily the width of a drift.

Much development work has been done on barren veins.

The fractures in which the veins occur are in places open for a width of 4 or 5 inches.

The conglomerate of the Cobalt series is a very coarse boulder variety; boulders a foot or two in diameter are common. One bed of slate-like greywacké was noted which in places rests directly on the Keewatin floor, as it likewise does in the Provincial mine immediately west of the Savage.

The Keewatin appears first on the 140-ft. level near the south boundary; this level produced the greater part of the ore.

The descriptions of the levels, beginning with the 240-ft., may now be given. These descriptions are substantially from the field notes of Mr. James Hill, who

geologically mapped and reported on the mine for the Ontario Department of Mines.

290-ft. Level.—The level was flooded at the time of examination. No. 2 vein was explored, but was found to be non-productive. The rocks are reported to belong to the Cobalt series.

240-ft. Level.—No. 2 and No. 10 veins have been opened up on this level. No. 10 was inaccessible at the time of examination, but was said to occur in Keewatin rocks and to be stoped for 120 feet. No. 2 vein was not accessible east of the winze. It is reported to have contained low-grade ore for 440 feet. Lenses of smaltite 3 inches wide were noted in No. 2 vein at the winze.

In the drift on No. 2 vein, a bed of slate-like greywacké may be seen resting on Keewatin at the winze. At the west end of the winze, the bed of slate-like greywacké dips 9° westward, and is about 15 feet thick. In the crosscut north of the winze, the greywacké bed dips northward.

190-ft. Level.—Only part of the workings around No. 2 vein were accessible. This vein was stoped for 100 feet in length, and its branch 70 feet; the latter is also stoped on the Provincial. On the Savage the branch of No. 2 vein occurs in a minor fault.

No. 10 vein is reported to have been stoped for 180 feet in length. Vein No. 23 produced some rich ore and has been stoped for about 80 feet.

The level is reported to be in conglomerate except in the vicinity of vein No. 6.

140-ft. Level.—Veins Nos. 3, 4, 5, 6, and 7 produced most of the ore which came from this level. No. 10 vein was richest from this level upwards, but yielded a greater tonnage below the level. The stopes average only 4 to 5 feet in width, as the silver did not penetrate the wall rock as far as it usually did in many other mines in the Cobalt area. A notable feature of the productive part of the veins is their chimney-like form. No. 10 vein, with a productive length of only 40 feet, yielded very rich ore. The ore-shoot of No. 23 vein was also chimney-like in form, the ore occurring below the level. The stope of No. 4 vein was 180 feet long; that of No. 3 vein was 130 feet long; that of No. 6 vein was 130 feet long; and No. 8 vein 200 feet long.

The level is almost entirely in conglomerate of the Cobalt series; much of the conglomerate is of the coarse boulder variety.

The Keewatin was met with in No. 6 and No. 11 crosscuts. In No. 6 crosscut the Cobalt series rests on a lamprophyre dike.

80-ft. Level.—None of the veins except part of No. 4 reach the surface. No. 4 vein was stoped for about 260 feet, and No. 3 for 250 feet. No. 5 and No. 6 veins produced little ore on this level. The level is all in conglomerate of the Cobalt series.

O'BRIEN

The O'Brien mine is owned by M. J. O'Brien, Limited, the head office of which company is in Ottawa, Ontario.

It has not been the policy of this concern to publish annual reports, the company being a close corporation; hence the costs of mining and treating the ore have not been made public, and the following account of the property is not as full as it might otherwise be.

The mine has produced 18,342,603 ounces of silver to the end of 1922, but the profits or dividends which have been paid from this substantial yield have not been made known.

About three-quarters of the silver, according to information furnished by the company, has been obtained from veins occurring in the Nipissing diabase

sill; these veins occur along the bottom of the sill. The rest of the silver produced was obtained from veins in the Cobalt and Keewatin series in about equal proportions. Thus, it may be said that the Nipissing diabase sill is economically the most important formation at the O'Brien mine, since it is responsible for three-quarters of the output of silver.

In the fall of 1921, the O'Brien was reported to be mining ore in No. 20 winze workings at a depth of 800 feet below the collar of No. 6 shaft. The ore at this depth was said to be largely a good grade of mill-rock, although some high-grade ore was also reported to have been mined. This ore occurs along the contact between the bottom of the Nipissing diabase sill and the underlying Keewatin.

In 1918 the company obtained most of its ore from the Keewatin basalt. In regard to this matter E. A. Collins reports: "It may be noted that of the ore broken [in 1918] 3,484 tons came from the conglomerate, 18,980 tons were in diabase, and 26,800 tons were mined in the Keewatin below the diabase sill."¹

There are three main vein-systems on the property, the No. 1, No. 6, and No. 20. Veins Nos. 1 and 6 strike between eastward and southeastward, are roughly parallel and about 500 feet apart. Towards the southeast, the two veins tend to approach each other, and to split into a number of branches. Vein No. 20 runs southeastward from vein No. 6.

No. 1 vein is probably the longest vein in the Cobalt area; it is the eastward extension of the McDonald vein on La Rose. If the veins on the Violet eventually prove to be the eastward extension of the O'Brien No. 1 vein-system, then the total length of this vein-system (including the McDonald on La Rose, the No. 1 vein on the O'Brien, and the Violet veins) will be about two-thirds of a mile. One of the stopes in this vein-system on the O'Brien is 900 feet long on the second level of No. 1 shaft. This stope extends into La Rose at least 445 feet.

While the No. 1, No. 6, and No. 20 veins are the principal veins on the property, there are a number of others of much less importance, the locality of which may be seen on the sheet showing the O'Brien, Violet, and Colonial workings.

The O'Brien mine is a good illustration of how the silver ore-shoots follow, in a general way, the contact of the bottom of the Nipissing diabase sill. The ore-shoots have been proven to occur within a zone about 100 feet above or below the bottom of the Nipissing diabase sill, but some of the shoots do occur as far as 200 feet above or below the bottom of the sill.

The bottom of the Nipissing diabase sill dips at angles of 10° to 25° eastward, but the dip becomes steeper on lower levels.

Since the ore-shoots follow the dip of the bottom of the diabase sill downwards, the surface outcrops of the veins towards the east are represented by little else than joint planes.

Generally speaking, it may be said that at the O'Brien, if there are ore-shoots in the Cobalt series between the bottom of the Nipissing diabase sill and the Keewatin, very little silver descends to the Keewatin; but, if the Cobalt series is absent, then ore-shoots may descend from the bottom of the Nipissing diabase sill down into the Keewatin basalt.

The stopes in the O'Brien mine examined by the writer are generally narrow, averaging between 5 and 10 feet in width. At junctions of two or more veins, however, the stopes are in places 15 to 20 feet in width. The stope at the west end of No. 1 vein, on the 50-ft. and 100-ft. levels, is as wide as 20 to 35 feet in

¹Annual Report, Ont. Bur. Mines, Vol. XXVIII, pt. I, 1919, p. 146.

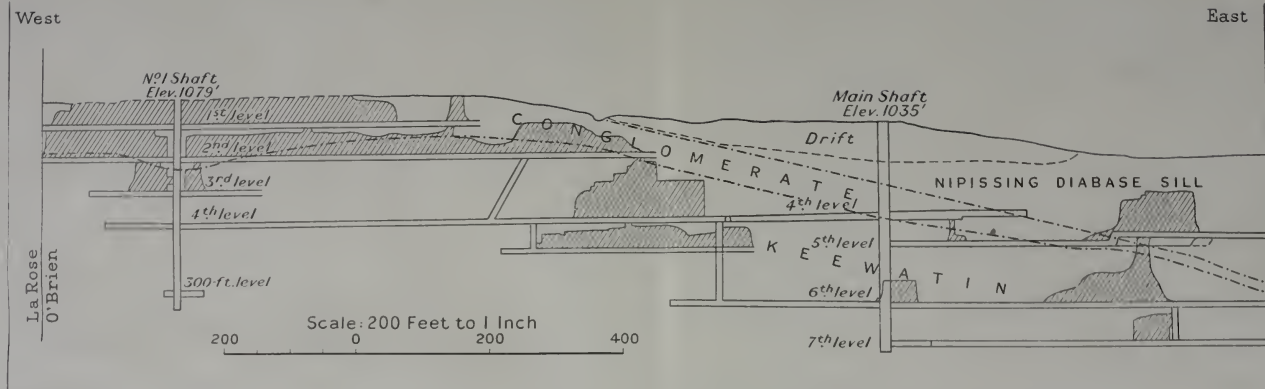


Fig. 26—Stope section on vein No. 1, O'Brien mine; section at the east end is incomplete. Furnished by O'Brien mine.

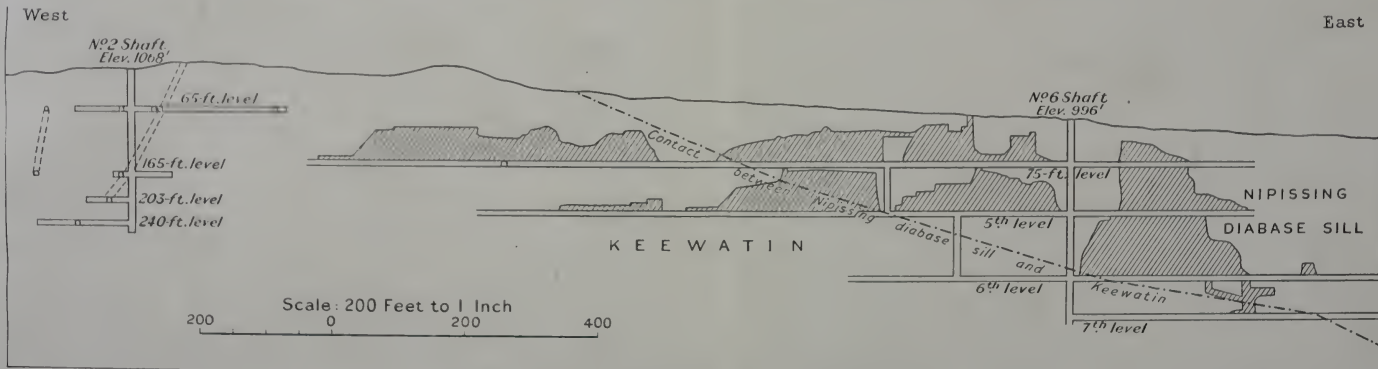


Fig. 27—Stope section on vein No. 6, O'Brien mine. The section at the east end is incomplete. Furnished by O'Brien mine.

places; this stope is in conglomerate and greywacké of the Cobalt series. The width of this stope may be seen in the open cut at the west end of the vein. The maximum depth of the conglomerate in this stope is about 100 feet.

The most prominent fault on the property is what has been called the O'Brien fault, which strikes between west and northwest. It has been encountered on the fourth, fifth, sixth, and seventh levels. The fault is about vertical, dipping 80° to 85° to the south, in places dipping locally to the north. It is similar in character and strike to the Violet fault on the east, and to the fault on the Chambers-Ferland, Nipissing, and Hudson Bay to the west. On the O'Brien it was reported to the writer that the fault yielded no silver.

About 100,000 ounces of silver had been obtained from veins north of the O'Brien fault to the end of the year 1921, this production having come from mill-rock containing 15 to 25 ounces of silver to the ton. Little high-grade ore of any consequence was mined north of the O'Brien fault.

The workings of the O'Brien mine, shown on the O'Brien, Violet, Colonial sheet, are, unfortunately, not complete. About three-quarters of the workings are shown. This is owing to the fact that at the time of our examination of the O'Brien, in the fall of 1921, a strip of land between the O'Brien and Violet mines was under litigation. In consequence of this lawsuit, the O'Brien workings in this disputed strip are not shown on our plans. Nor do the plans show the workings below the seventh level. These workings below the seventh level are from winze No. 20 and follow the extension of vein-system No. 20 along the contact between the bottom of the Nipissing diabase sill and the Keewatin basalt.

Description of O'Brien Mine Workings

At the end of the year 1921, there was a total of about 12 miles of drifts, crosscuts, raises, winzes, and shafts.

Workings below Seventh Level.—There are reported to be about 4 or 5 miles of drifts, crosscuts, winzes or raises in the workings below the seventh level. The lowest level is 800 feet below the collar of No. 6 shaft. At the request of the management, the Ontario Department of Mines did not make a detailed examination of these workings, nor are the plans published in this report. A few hours were spent with the assistant manager in a casual examination, and it was observed that on one of the lower levels the contact of the bottom of the Nipissing diabase sill with the Keewatin was at one place very steep—in the neighbourhood of 60° or more.

From time to time, since the year 1914, certain information regarding these lower workings has been published in the reports of the inspectors of mines for the Province of Ontario. For convenience this information is given below.

In 1915, J. G. McMillan¹ reported as follows:—

During the year [1914] the winze [No. 20] from the 300-ft. level of the No. 6 shaft was sunk to a depth of 200 feet, cutting the diabase-Keewatin contact at 180 feet, or 480 feet from the collar of the shaft. In this winze three levels have been opened, some new ore put in sight, and ore proved to exist below the lowest level.

In 1916, James Bartlett² reported:—

The winze, No. 20, from the 300-ft. level of No. 6 shaft has been sunk to a depth of 250 feet and four levels have been opened.

In 1917, James Bartlett³ wrote:—

A new level was established at 610 feet.

¹Annual Report, Ont. Bur. Mines, Vol. XXIV, pt. I, 1915, p. 121.

²Ibid, Vol. XXV, pt. I, 1916, p. 119.

³Ibid, Vol. XXVI, 1917, p. 123.

In 1918, E. A. Collins¹ reported as follows:—

A new low level was established at 720 feet below the collar of the main shaft and ore mined at this level.

In 1919, J. G. McMillan² reported:—

During the year a new winze level was established at 800 feet below the collar of No. 6 shaft.

Seventh Level.—(700 feet above sea level at main shaft.) Vein No. 6 at the west end in the Keewatin occupies a fault dipping 50° to 60° north, and having a fault breccia and gouge 2 or 3 inches to a foot or more in width. In places there is a quartz and calcite vein in the fault, but the vein has not been productive in the Keewatin. Where this vein enters the diabase about 350 feet east of No. 6 shaft it becomes productive, and a stope some 300 feet in length has been developed. The stope is about vertical, so that as vein No. 6 went from the Keewatin into the Nipissing diabase it evidently became vertical and, also, productive of silver. The fault is in the Keewatin series; we were not able to observe if this fault enters the diabase, but it was observed that farther southeast this vein is not in a fault.

Vein No. 6 pinches out about 50 feet northwest of No. 20

No. 20 vein is an important one, and has a stope on this level about 250 feet long. This stope begins at winze No. 20, and is wholly in the Nipissing diabase on this level.

For about 500 feet east of the main shaft, No. 1 vein in the Keewatin is for the most part only fractions of an inch in width, consisting of calcite. As the vein approaches the Nipissing diabase it becomes wider, and finally ore develops in it; a stope three or four hundred feet long has been mined. A vein of unusual shape crosses at right angles the No. 1 vein near the east end; this vein forms a huge semi-circle, and has a stope some 600 feet long.

At the north end of the workings there is a vein striking about east and west which follows the north side of a small lamprophyre dike. This vein was not productive on the seventh level, but was being stoped on the level above in October, 1921. The ore was not high-grade, but was a fair grade of mill-rock.

The rocks on the seventh level consist largely of the Keewatin series with a smaller development of the Cobalt series and Nipissing diabase at the east end. The Keewatin is made up of basaltic rocks, except at the north part of the workings where finely bedded cherty rocks of the "iron formation" occur. The Cobalt series at the northeast part of the level consists of easily recognizable conglomerate and greywacké, but towards the southwest the Cobalt series consists of decomposed Keewatin which is difficult to distinguish from the Keewatin along the contact.

The O'Brien fault is met with in a crosscut about 150 feet north of No. 1 vein. The fault consists of about 15 inches of fault breccia and gouge, and it contains a little galena, zinc blende, and iron pyrites; it dips steeply south. The fault follows the contact between the finely bedded cherty rocks of the "iron formation" on the north and the basalt on the south.

Sixth Level.—(755 feet above sea level at main shaft.) The contact between the Nipissing diabase and the Keewatin occurs in No. 6 shaft about 13 feet above the level. In the vicinity of No. 6 shaft it may be seen that vein No. 6 is vertical in the Nipissing diabase and that, when it descends and enters the Keewatin, it dips at about 50° to the north. It would appear that the vein in the Keewatin

¹Annual Report, Ont. Bar. Mines, Vol. XXVII, pt. I, 1918, p. 125.

²Ibid, Vol. XXIX, pt. I, 1920, p. 104.

follows an old fissure of pre-diabase age. The fissure shows an inch or two of fault breccia and contains quartz which is probably older than the calcite. For 500 or 600 feet in the vicinity of winze No. 20, the No. 6 vein is little else than a vertical joint plane in the diabase containing fractions of an inch of barren calcite. The southeast face of this drift shows a crack containing a little gouge. This part of the vein southeast of winze No. 20 is evidently too high above the contact between the diabase and Keewatin to be productive. The vein is for the most part frozen to the diabase walls. East of No. 6 shaft there is a stope in the diabase 250 feet long.

Vein No. 1 just east of the main shaft splits, the two branches continuing eastward for about 200 feet and eventually joining again. The two branches contain usually less than one inch of calcite. Opposite the shaft the vein is 3 or 4 inches in width of calcite.

Vein No. 16 strikes about northward. It has 2 stopes, one about 275 feet long, and the other less than 100 feet long. The O'Brien fault crosses vein No. 16 about at right angles. For 20 or 30 feet on the north and south side of the fault, vein No. 16 appears to pinch out save for irregular stringers.

The O'Brien fault occurs near the north end of the level, and has been drifted on for nearly 400 feet, but no ore was found. Galena, iron pyrites, zinc blende, and a very little calcite occur in it. The fault contains from one-half to three-quarters of an inch of gouge, and 1 to 4 feet of fault breccia. It strikes W. 16° N. and dips 70° to 75° south; locally it dips to the north.

The rocks on this level consist of Keewatin and Nipissing diabase in about equal proportions, together with a belt of the Cobalt series. The Keewatin is made up largely of basalt, but at the north end of the level it consists of "iron formation" having a width of at least 300 feet. The "iron formation" is made up of chert, greywacké, and quartzite-like rocks. The "iron formation" dips steeply southward, and strikes westward about parallel to the O'Brien fault. Indeed, the O'Brien fault on this level and the seventh follows the contact between the "iron formation" and the Keewatin basalt.

This "iron formation" was found on the Violet mine to the east of the O'Brien.

Fifth Level.—(850 feet above sea level at main shaft.) This is the most extensive level in the mine, reaching as it does almost from the north end to the south end of the property. The noteworthy piece of development work is a crosscut almost half a mile long in the Nipissing diabase, intersecting veins No. 1 and No. 6, and some others which were not productive.

On vein No. 6, just west of No. 6 shaft, there is a stope about 500 feet long for the most part in the diabase, while at the west end of the vein there is a small stope 150 feet long which is in the Keewatin.

On No. 1 vein there is a stope about 300 feet east of the main shaft; this stope is in the diabase and is about 150 feet long.

Vein No. 16 has been stoped up to the surface, and the upper part was being worked as an open pit in the fall of 1921.

On the plan of the fifth level, there are shown certain workings at the northeast end of the O'Brien property. These workings are not connected with the main shaft on this level; but the workings may be reached from No. 14 shaft, or by going up a raise from the sixth level at the north end. Vein No. 16 and a vein farther east have been worked from this level, with small stopes, partly on the Nipissing property and partly on the O'Brien property. The workings are all in the Cobalt series except at the east, and where a drift just enters the Nipissing diabase.

The fifth level workings are connected with the No. 33 shaft at the southwest corner of the property; and the second level of the No. 33 shaft corresponds to the fifth level of the main shaft. The fifth level at the No. 33 shaft was run to work vein No. 33, which was followed for 500 feet. In places this vein attains an unusual width—from 12 to 15 inches of white calcite. The contact of the Nipissing diabase and Keewatin basalt occurs at the shaft, and is irregular in outline as the plan shows.

There are a number of interesting faults on this level, chief of which is the O'Brien fault at the northeast end of the level. Here the fault is in the Nipissing diabase, and has been followed for some 50 feet. It has an unusual dip on this level, 75° to the north, whereas, as a general rule, it dips to the south. The fault breccia and gouge is about one foot wide and, in places, the rock is crushed for four or more feet. The rock falls readily from the back, making mining operations dangerous.

Southwest of No. 6 shaft 650 feet, there is a minor fault striking a little north of east. The gouge and fault breccia are from half an inch to about 3 inches in width, being widest at the east end. Possibly this fault explains the presence of the valley on the surface in this part of the O'Brien. Cutting about at right angles to this fault, there is another one about 30 feet west of the main crosscut. The fault shows from 1 to 3 inches of gouge and breccia and appears to strike about parallel to the diabase contact. A similar fault to this occurs at the south end of the property, and it also strikes about parallel to the diabase contact.

Fourth Level.—(885 feet above sea level at main shaft.) No. 1 vein has been drifted on for about one-quarter of a mile. This vein is almost wholly in the Keewatin basalt. Where examined, it is but a few inches in width and, at the east end, it pinches out to a mere joint crack. The west end of the level was flooded and inaccessible. West of the main shaft there is a stope about 200 feet long in Keewatin. From this stope west to No. 1 shaft there are no other stopes.

The O'Brien fault was met with on this level at the northeast part of the workings and was followed for about 300 feet. It strikes about W. 20° N. and dips 85° to the south, although locally it is practically vertical or even dips steeply to the north. The fault has about a foot of fault breccia and gouge, and a vein of calcite about an inch wide occurs here and there in the fault. In places the fault is rusty.

A crosscut runs northward from the fault, passing No. 14 shaft, to the north boundary between the O'Brien and Nipissing properties. Exactly on the boundary line there is an east and west crosscut 600 feet in length, the cost of which was shared jointly by the O'Brien and Nipissing companies. The Keewatin was encountered at the west end of this crosscut, consisting of rusty cherty rocks of the Keewatin "iron formation."

Third Level.—(No. 6 shaft, 921 feet above sea level at No. 6 shaft and 75 feet below collar of No. 6 shaft.) This level was worked originally from No. 6 shaft. It is, as a matter of fact, the first level from No. 6 shaft, but is known as the third level. No. 6 vein has been drifted on for nearly 1,500 feet. Immediately west of the shaft, there is a stope nearly 500 feet long in Nipissing diabase; at the west end there is a stope about 450 feet long which is in Keewatin.

In places where No. 6 vein could be seen, it varied in width from fractions of an inch to six inches or a little more. Part of the stope at the west end was accessible, and in the back the vein was seen to be in places as wide as six inches. The stope was 5 or 6 feet wide.

At the west end of the drift, there is a fault of importance with a fault breccia and gouge of three or four inches. The fault dips to the north about 55° , and the vein appears on each side of the fault; what the displacement of the vein has been, if any, was not apparent.

The rocks on the level are Keewatin basalt and Nipissing diabase in about equal proportions.

Third Level.—(No. 1 shaft, 929 feet above sea level at No. 1 shaft, 150 feet below collar of No. 1 shaft.) This level was not examined, nor is it shown on our plans. It has a length of 265 feet; there is a stope west of the shaft 60 feet long, and a stope east of the shaft 30 feet long.

Second Level.—(No. 1 shaft, 979 feet above sea level at No. 1 shaft, 100 feet below collar of No. 1 shaft.) The stope on No. 1 vein on this level is 900 feet long, partly in rocks of the Cobalt series, and partly in Keewatin rocks. At the east end of the stope there is a fault dipping at some 20° or 30° to the east. No ore has been found above the fault in this part of the mine. In other words, this fault limits the eastward extension of the ore. The vein continues eastward, but does not become productive again for some distance east of the main shaft. This fault is another instance of how a fault limits the deposition of the silver ore at Cobalt.

In the vicinity of the fault, at the east end of the drift, there is on the walls of the drift in places a thin coating or film of bluish-black, oily-looking material. A sample of this material was taken by scraping it off the walls of the drift. In doing this, much of the finely powdered rock which clings to the walls of all mine workings in Cobalt, was mixed with the sample, so that the quantity of the bluish-black material in the sample was small compared to the quantity of powdered rock. But, in spite of this dilution, the sample was found to contain 100 ounces of silver to the ton. It is quite evident that this coating is of secondary origin and has been deposited on the walls of the drift after mining operations had ceased. No mining has been done in this part of the drift for five or six years.

Material similar to this was first noted at the Crown Reserve mine about ten years ago. At that time a sample was submitted to W. K. McNeill, Provincial Assayer for Ontario, who considered the material might be a mechanical mixture of finely powdered, silver-bearing minerals. In the old workings of other mines at Cobalt, this material has also been observed occurring under similar conditions.

The level is in the Keewatin and Cobalt series. The Keewatin "iron formation" is present. The contact between the Cobalt series and Keewatin is in the shaft a few feet below the level.

First Level.—(No. 1 shaft, 1,029 feet above sea level at No. 1 shaft, 50 feet below collar of No. 1 shaft.) This level is now mostly an open cut nearly 500 feet long, all in conglomerate and greywacké of the Cobalt series. At the west end, two veins, striking southward from the Chambers-Ferland, join the No. 1 vein. In the vicinity of the junction the open cut is about 35 feet wide.

The level is all in conglomerate and greywacké of the Cobalt series except at the south end of a crosscut at the east end of the level where there is about eight feet of Keewatin.

Workings from No. 2 Shaft.—This shaft is 900 feet south of the northwest corner of the property. It was sunk in order to mine the southeastward extension of La Rose veins known as Nos. 3 and 6. On the O'Brien property these veins are unfortunately all in the Keewatin series.

At the time of our examination, in October, 1921, only the first level was accessible. There are four levels.

The first level is 65 feet below the collar of the shaft. There are half a dozen veins on the level, all of which are in Keewatin basalt. The most westerly one has been drifted on for about 275 feet, and there is a small stope at the south end; the vein shows one or two inches of calcite. East of the shaft another vein has been drifted on for about 200 feet, and there is a stope about 100 feet long. This stope goes to the surface and shows the vein to have an unusually flat dip—at the south end 35° to 38° , at the north end a little steeper.

At the east end of the workings, there is a well-defined fault which has been followed for about 100 feet; it strikes northeast and dips about 25° to the northwest. The fault shows an inch of gouge in places, and from six inches to two feet of fault breccia. A calcite vein, three or four inches wide, shows in the back of the drift; its relation to the fault was not noted.

In several places there are lamprophyre dikes on this level.

Workings from No. 33 Shaft.—This shaft is at the southwest corner of the property. There are two levels, at 100 feet and 180 feet below the collar of the shaft. The 180-ft. level has been described in dealing with the fifth level.

The first level from No. 33 shaft follows a vein for 400 feet. The vein strikes southwestward and occurs in the Nipissing diabase at the northeast part and in Keewatin basalt at the southeast part. The vein consists of calcite which varies in width from a fraction of an inch to one or two inches, while in the northeast face it is a mere crack. A small stope about 60 feet long and 25 feet high was mined at the southwest part of the vein, along the Keewatin-Nipissing diabase contact.

The diabase contact occurs on the level below at the bottom of the shaft, a few feet west of the station.

TEMISKAMING

The Temiskaming Mining Company, Limited, has an authorized and issued capital of \$2,500,000 in shares of the par value of \$1.00. To November, 1920, when the company ceased operations, the mine had produced 11,721,433 ounces of silver, and had paid \$2,159,156 in dividends. This large output was obtained from eight acres of ground. There are about nine miles of underground workings, including drifts, crosscuts, winzes, raises, and shafts.

The Temiskaming Mining Company owns half of the capital stock of the Blue Diamond Coal Company, Limited, the mines and plant of which are at Brule, in the Province of Alberta. The remaining half of the stock of the Blue Diamond Coal Company, Limited, is owned by the McIntyre Porcupine Mines, Limited.¹

The general manager at the time the plant closed in November, 1920, Mr. Gordon F. Dickson, in discussing the reasons for the closing down of the Temiskaming, stated that the price of silver fell during the year 1920 to such a low level that profitable operation was not possible in view of the high cost of labour and supplies; these factors, combined with the shortage of power due to the dry season, caused the plant to cease operations. In regard to the finding of more silver ore, Mr. Dickson stated that the likelihood of discovering any quantity of high-grade ore in the old workings was small. He thought, however, there was scope for opening up a considerable tonnage of medium-grade ore which would show a profit with silver at 70 cents an ounce.²

¹Report of the Temiskaming Mining Company, Limited, for the eighteen months ended June 30th, 1921.

²Ibid, page 12.

Structure

The structure of the rocks, and the relation of the veins to the rocks at the Temiskaming, is shown in the coloured cross-sections facing page 32. Take, for instance, the section marked D-D through the main shaft of the mine. It will be seen that the Nipissing diabase sill is shown intruding the Keewatin rocks, and that the sill has a thickness of about 1,000 feet. The Keewatin consists of what appear to be two lava flows of basalt, separated by a bed of finely banded chert and greywacké, known as "iron formation", but which in this description will be called the chert bed. It is 100 to 200 feet thick, dips about vertically, and strikes a little east of south. The basalt adjacent to the chert on the west is generally rusty, owing to the presence of iron pyrites which is partly weathered to limonite. The vertical section shows the chert formation below the diabase



Fig. 28—Temiskaming shaft-house.

sill, but its exact position there was not ascertained, as the 1,600-ft. level was not accessible; nor is it known to the writer whether the mine workings intersected the chert. The hanging wall and footwall of the diabase sill may have been displaced relatively to each other during the intrusion of the diabase, in which case the chert below the sill may be difficult to find. Its strike below the sill might be different from its strike above it, depending on the character of the movement between the footwall and hanging wall of the sill.

The position of the veins in relation to the top of the sill is shown in the sections. It will be noted that the veins in the diabase dip to the westward, about at right angles to the dip of the top of the sill. In fact, the veins appear to occur in joint planes in the diabase; these joint planes are about at right

angles to the contact. As the veins emerge upwards from the top of the sill, they become vertical for a short distance above the contact and then dip steeply eastward.

Attention may be directed to what has the appearance of being a sharp fold in the Nipissing diabase sill, shown at the west side of the vertical sections facing page 32. It is doubtful, however, if this sharp irregularity in the sill was caused by folding. The writer could not find proof of folding. Rather would it appear that the sill was intruded through the Keewatin rocks in this irregular form. The occurrence, however, of the silver-bearing veins just to the east of this sharp irregularity may be pointed out. The question naturally arises: Will silver be found in commercial quantities below the sill under similar structural conditions?

Intruding the Keewatin rocks are many lamprophyre dikes and sills of Haileyburian age, several feet in width. The veins are, of course, younger than these dikes.

A dike of basalt, about a foot wide, has been found on the 385-ft. and 499-ft. levels. It appears to be younger than the veins, although this is not definitely proven.

Veins

The vein-system of the Temiskaming and Beaver consists mainly of two parallel veins, 200 to 250 feet apart, striking a little east of north. The system has a length of approximately 2,400 feet. The Temiskaming owns the southern two-thirds and the Beaver the remaining part to the north. The entire system yielded 18,293,216 ounces of silver, of which quantity the Temiskaming has produced 11,681,900 ounces.

The Temiskaming-Beaver system is an isolated one, removed as it is almost a mile from the nearest productive vein, namely, No. 3 vein at the southeast corner of the Kerr Lake property. The productive part of the veins was terminated at the north end of the Beaver by a fault, to the north of which no silver has yet been found, although some of the veins, consisting of barren calcite, do extend north of the fault.

The ore at the Temiskaming occurs wholly at the top of the Nipissing diabase sill, both in the sill and in the overlying Keewatin, most of it having been mined from veins in the Keewatin. The ore bodies of the Keeley and Frontier mines in South Lorrain occupy similar structural positions. The writer was informed that more than three-quarters of the ore at the Temiskaming came from within about 125 to 150 feet of the contact. While most of the ore came from near the contact, it may be noted that one shoot of high-grade ore was mined 40 feet below the surface, and that mill-rock was obtained at the surface about the time the company ceased mining in the autumn of the year 1920. Reference to the richness of the ore along the contact is made in the annual report of the company for the year 1915.¹ The report states that along the contact, both above and below, the Temiskaming and Beaver have recovered their richest values.

As illustrating the richness of the ore at or near the upper contact of the Nipissing diabase sill, the shipments for the year 1910 may be referred to. The high-grade ore produced that year by hand-sorting amounted to 376 tons, the average assay value of which was 3,562 ounces. One 32-ton car assayed as much as 4,423 ounces of silver per ton. The major portion of these 376 tons came from the 396-ft. level. From the level below this, namely, the 499-ft., one car of 25 tons was shipped which contained a total of 202,806 ounces of

¹Annual Report, Temiskaming Mining Company, for year 1915, p. 5.

silver, and netted \$117,962. This car was shipped in the year 1912 and was the richest per ton car lot ever shipped from Cobalt up to that time, according to the company's statement.¹

While all of the silver was obtained from veins at the top of the diabase sill, it may be added that a vein was found below the sill on the 1,600-ft. level; it did not, however, produce silver.

The greatest depth below the surface from which the ore was mined was about 800 feet.²

Of the two main veins, referred to above, the westerly one is No. 19; its northward extension into the Beaver is known as No. 3 vein. The easterly vein is known as the No. 1 and No. 3; its northward extension into the Beaver is known as the No. 5 vein.

The coloured section, facing page 10, shows the stoped portions of veins Nos. 1 and 3 on the Temiskaming and vein No. 5 on the Beaver.

Vein No. 19 was first discovered on the Beaver, where it was known as vein No. 3. In view of the importance of this vein on both properties, we publish elsewhere in this report, on page 150, an account of its discovery, as written by Mr. F. L. Culver, president and general manager of the Beaver, and president and general manager of the Temiskaming at the time of the discovery of the vein.

The ore-shoots in some of the veins occur in such an irregular and erratic manner that it was impossible to accurately estimate the ore reserves from year to year. Mr. Norman R. Fisher, who was general manager until the year 1914, makes the following comments regarding the difficulty in estimating ore reserves.³

Notwithstanding that I have been in close touch with this property since its infancy, thereby gaining a very intimate knowledge of the occurrence and intricacies of its ore bodies, still the estimation of its ore reserves is to me an enigma the solution of which I hesitated to approach.

Though the various veins are exceptionally persistent both in depth and strike, they prove very erratic in values, so much so that it is practically impossible to gauge within reasonable limits one way or other the quantity of silver they contain.

Likewise as regards the milling reserve I can but reiterate the opinion voiced in my last report as to the utter impossibility of doing this justice. Here the values are also irregular and the ore not only occurs as mineralized zones, traversed by rich narrow streaks, but as lenses and pockets of high-grade distributed throughout otherwise lean but strong calcite veins.

The productive parts of the Temiskaming vein-system extended into the Gans ground on the south, a distance of only about 250 feet. The Gans lot is owned by the Temiskaming and constitutes the south part of the Temiskaming property. Not much silver was discovered in the middle and south parts of the Gans. At one time, however, it looked as if important quantities of high-grade ore would be found in vein No. 506, but development work proved disappointing; it was stated that only in the neighbourhood of some 10,000 ounces of silver were recovered. This vein occurs in about the middle of the Gans lot, and about 150 feet west of the east boundary; it roughly parallels section line 500 on the 499-ft. level. Regarding the discovery of this vein, the following is quoted from the annual report of the company.⁴

In the middle of April [1919] a pocket of high-grade ore was found at the 499-ft. level in 506 vein on the Gans property. Subsequent development disclosed other rich patches in this vein, but although, owing to their irregular occurrences, the tonnage obtained from this source has been comparatively small, there is encouragement for the belief that the development scheme now in progress in this southern area of the property may ultimately disclose more permanent enrichment in the veins.

¹Sixth Annual Report, Temiskaming Mining Company, Limited, December 31st, 1912, p. 16.

²Eighth Annual Report, Temiskaming Mining Company, Limited, December 31st, 1914, p. 14.

³Fourth Annual Report, Temiskaming Mining Company, Limited, February 18th, 1911, p. 28.

⁴Annual Report, Temiskaming Mining Company, Limited, year ending December 31st, 1919, p. 10.

Copper

The occurrence of copper in the mine is of interest. The report of the company for the year ending December 31st, 1912, states that 16,037 pounds of copper were sold, for which \$1,133 was received, this being the first instance in the history of Cobalt in which copper was produced in economic quantity.

Special Examinations

Towards the end of the time that the ore reserves of the Temiskaming began to play out, the company had four special examinations and reports made. These reports were made by Mr. R. J. Ennis, consulting engineer for the company, Mr. Balmer Neilly, Mr. Douglas Mutch, and Mr. A. R. Whitman, geologist.

The report by Mr. R. J. Ennis gives a first-class summary of the history of the mine from its beginning to the middle of the year 1918. The following is quoted from the report by Mr. Ennis, dated July 3rd, 1918.¹

During the last four months the mine has been carefully examined, plans and sections made of the workings and a geological examination made by Mr. A. R. Whitman, from all of which has been outlined a plan of exploration.

The broken ore reserves were exhausted in the latter part of April and as only a few faces in the mine were producing ore, the concentrator was shut down and all machines were put on exploratory work.

The mine started to ship silver in 1908 and for ten years has shown a varied production. The annual reports of the Company also show equally varying ore reserves, bringing out the fact that the ore shoots in the veins on the property are of most irregular occurrence.

The operation of the mine may be divided into two periods. First, from the beginning of production in 1908 to the end of 1913, when Veins Nos. 1 to 16 were worked and reached their maximum production, yielding 142,818 tons of ore, from which 7,173,360 ounces of silver were recovered, or 50.2 ounces per ton, including both high-grade and mill-rock. To make this production possible 21,851 feet of development work was done, or one foot for every 328 ounces of silver obtained. In the second period, from 1914 to the end of 1917, Veins Nos. 19 to 21 were opened up and together with a small tonnage from the ends of Veins Nos. 1 and 16 produced 91,595 tons of ore yielding 3,664,559 ounces of silver or 40 ounces per ton of ore mined. Seventeen thousand six hundred and fifty-two feet of development work was performed in this period, or one foot for every 207½ ounces of silver obtained.

All the productive veins on the property have been found in about eight acres of ground in the west half of the Temiskaming Lot. On the levels of the mine within this area above the diabase sill and on the 575-, 650- and 725-foot levels in the diabase 38,000 feet of crosscuts, drifts, raises and winzes have been driven. This work has thoroughly prospected the ground, leaving but little chances of finding any extensive ore bodies in this territory.

From Mr. Whitman's report, printed herewith, it will be noted that the productive veins run north and south over a trough in the diabase sill and that a similar trough exists in the diabase in the Gans Lot. The veins on the Temiskaming and Beaver mines no doubt belong to the same system, which has been productive over a trough or basin in the diabase sill 1,300 feet wide, the southern arch being in the north end of the Gans Lot and the northern arch being four hundred feet in the Beaver Property. From this whole system has been produced to January 1st, 1918, approximately 433,000 tons of ore yielding about 16,000,000 ounces of silver. The trough in the Gans Lot is probably 900 feet wide, in which are favourable chances of finding a new vein-system containing high-grade ore-shoots. An exploratory programme has been laid out to thoroughly prospect the Gans Lot above the diabase sill and the Gans and Temiskaming Lots below the diabase sill on the 1,600-foot level. This programme will be completed in six months and in the meantime prospecting will be continued in the old vein system.

The trough referred to by Mr. Ennis is shown on the coloured section opposite page 10. This section is drawn parallel to veins Nos. 1 and 3 on the Temiskaming and No. 5 on the Beaver.

Regarding the reports of Mr. Balmer Neilly and Mr. Douglas Mutch, the following is quoted from a report to the shareholders by the mine manager, Mr. I. S. McReavy.²

¹Special Report to Shareholders, Temiskaming Mining Company, Limited, 1918, pp. 4-5.

²Special Report to Shareholders, Temiskaming Mining Company, Limited, 1918, p. 5.

The operation of the mine was taken over by the present management on February 7th of the current year [1918] and, after thoroughly examining the mine and ore records, it was found that the estimate of ore reserves made by Mr. Balmer Neilly on August 7th, 1917, and by Mr. Douglas Mutch, on October 31st, 1917, were practically correct. From the date of Mr. Neilly's report to February 7th, 1918, 566,180 ounces of silver were produced, 2.8 per cent. more than the amount estimated. From the date of Mr. Mutch's report to February 7th, 1918, 304,444 ounces of silver were produced, 22.8 per cent. less than the amount estimated.

Mr. McReavy has, in the following table, summarized the operations of the company since its incorporation to December 31st, 1917.¹

	Pro- gress	Shipping production		Positive ore reserves		Ounces per ft. of develop- ment (on ore hoisted)
	feet	tons	ounces	tons	ounces	
9 months to 31st Jan., 1908.			452,229			
12 months to 31st Jan., 1909.			976,027			
Previous to 31st Jan., 1909.	3,110					
31st Jan., 1909, to 31st Jan., 1910. .	3,082	794.298	682,861	74,220	3,298,000	380.2
31st Jan., 1910, to 31st Dec., 1910. .	3,042	1,029.210	1,872,708	118,681	4,805,532	607.2
1st Jan., 1911, to 31st Dec., 1911. .	3,586	909.000	1,213,754		Not estimated	296.1
1st Jan., 1912, to 31st Dec., 1912. .	4,645	1,004.200	1,242,243		Not estimated	227.8
1st Jan., 1913, to 31st Dec., 1913. .	4,397	572.100	739,726		Not estimated	193.9
1st Jan., 1914, to 31st Dec., 1914. .	2,791		278,961		Not estimated	100.0
1st Jan., 1915, to 31st Dec., 1915. .	4,763		1,456,894		Not estimated	305.9
1st Jan., 1916, to 31st Dec., 1916. .	5,243		963,848		Not estimated	183.8
1st Jan., 1917, to 31st Dec., 1917. .	4,896		958,670		Not estimated	195.8
	39,555		10,837,921			

	Cost per oz. (on ship- ping pro- duc- tion)	Mar- ket price per oz.	Profit per oz.	Ore hoisted, cost per ton	Ore milled, cost per ton	Net profit
	\$	\$	\$	\$	\$	\$
9 months to 31st Jan., 1908.						
12 months to 31st Jan., 1909.						
Previous to 31st Jan., 1909.						
31st Jan., 1909, to 31st Jan., 1910. .	0.349	0.520	0.171	13,063		75,178.30
31st Jan., 1910, to 31st Dec., 1910. .	.177	.540	.363	17,917	15,250	691,713.88
1st Jan., 1911, to 31st Dec., 1911. .	.311	.540	.229	15,220	10,863	271,423.09
1st Jan., 1912, to 31st Dec., 1912. .	.292	.606	.314	11,525	9,049	413,150.38
1st Jan., 1913, to 31st Dec., 1913. .	.434	.598	.164	9,936	9,932	117,574.02
1st Jan., 1914, to 31st Dec., 1914. .	.903	.490	loss.413	unavail- able	unavail- able	81,422.35 loss
1st Jan., 1915, to 31st Dec., 1915. .	.198	.497	.299	"	10,710	443,864.17
1st Jan., 1916, to 31st Dec., 1916. .	.402	.657	.255	"	11,770	321,666.87
1st Jan., 1917, to 31st Dec., 1917. .	.373	.819	.446	10,683	11,235	518,556.92

Extracts from Mr. A. R. Whitman's report² are given below:—

The diabase sill is the formation of chief interest, because it was the source of the silver ores of the district. They emanated from it, in a state of solution, and were deposited in the form of mineral, in fractures adjacent to the margins of the mother formation. In the Keewatin, and in the diabase itself, commercial ore bodies occur only within 350 feet of the margins of the sill.

¹Special Report to Shareholders, Temiskaming Mining Company, Limited, 1918, p. 7.

²Special Report to Shareholders, Temiskaming Mining Company, Limited, 1918, pp. 12, 13.

The configuration of this sheet of igneous rock is significant, and is due to the fact that it was injected into its present position in a molten condition. The wedge-like advancing edge of the molten mass worked its way along a nearly horizontal line of fracturing, being compelled to pursue, frequently, more or less wavy courses. As it advanced it lifted up the great mass of overlying Keewatin formation which at that time extended above the horizon of the present surface. After the entire body of molten diabase had come into place, and had consolidated into cold rock, certain compressive forces in the earth's crust became active to the extent of slowly bending the sill into folds, which tended to form along the undulations which already existed in its configuration. That is, the undulations were accentuated by the folding.

These processes developed fractures which bore certain relations to the sides of the folds; and those fractures afterwards became filled with the ore minerals, which diffused into them from the sill, making the present veins.

It is by determining the configuration of the sill, and the localities and directions of folds and fractures, that it is possible to know where conditions were favourable for the deposition of good veins.

It has been found that where there has been folding, flatly inclined joints, faults and shear-zones have been produced parallel to the sides of the folds. And it has also been found that they have served as feeders of mineral to the veins; so that the richness of the ore bodies is, to a considerable extent, proportional to this flat shearing, and to the acuteness with which the troughs and arches have been compressed. Thus, the richest veins should be found on the sides of, or spanning such folds, where there has been much shearing in the adjacent diabase.

It is also important to bear in mind that the undulations in the lower margin of the sill must correspond to those in the upper margin, since the two are parallel. And an arch of Keewatin under the sill may be as favourable a place for ore as a trough in the upper margin.

Cases.—The development outlined on the 1,600-ft. level is a case in point. The east crosscut is designed to diagonally cross the axis of an arch in the Keewatin under the sill. It is expected that veins would be found crossing the arch, and that the arch would be found to have been compressed to such an extent that shearing would have been developed on its sides, in the sill, adequate to have produced commercial ore bodies in the veins.

Virtually the entire production of the Temiskaming mine has come from fractures which crossed a trough in the upper margin of the sill. This trough pitches eastward, and its axis is concave upward, the good veins occurring only where its slope lies between 10 and 25 degrees. The sides are well sheared on the margin of, and within the sill, thus making favourable conditions for the supply of mineral to the veins. It is important to note that although the shearing continues into the interior of the sill, it is only near the margins that it affects their richness. This is because the individual fractures are not persistent, and mineral drained from the interior by them cannot be contributed directly to a common seat of deposition, but must find its way to the margin, where the shearing is continuous and more concentrated. Thus it can be only from the margin of the sill, or from the marginal region, that mineral could have been fed in commercial quantities to any given vein. The only exception to this would be a very strong and persistent shear-zone within the sill. But such a thing is not known to exist in this property, the shear-zone found in the shaft just below the 1,400-foot horizon not being of sufficient importance to fall in this class, nor to be of any other significance.

The Discovery of the Temiskaming Mine

BY CHARLES A. RICHARDSON

For the following very interesting account of the discovery of the Temiskaming mine, the Ontario Department of Mines is indebted to Mr. Charles A. Richardson, one of the pioneers at Cobalt. The plan of the 80-ft. level, referred to by Mr. Richardson, is not shown on the Beaver and Temiskaming Sheet, No. 31a-1.

Early in the year 1905 a syndicate was formed by Mr. R. A. Cartwright, Mr. J. L. Wheeler, and the writer, for the purpose of exploring for or otherwise securing ground of possible merit in the Cobalt area. Later we associated Mr. B. E. Cartwright with us by dividing our original syndicate shares into four instead of three parts; and this proved fortunate for us, as it was largely through Mr. B. E. Cartwright's efforts that the large expenditures, that were entailed in bringing this property to a producing state, were arranged for.

A claim of twenty acres, which later became the north half of the Temiskaming mine, was staked by Alex. Daigle, at that time an employee of the Vendome Hotel at Haileybury, under an arrangement with the writer whereby I secured a one-half interest for doing the statutory assessment work on the ground with an option on the one-half interest which he still owned. These options were taken by me for the benefit of myself and associates, and I commenced prospecting work on this claim during the latter part of April, 1906. The first stripping and trenching was done near the central part of the claim, which consisted of twenty acres, at a point about five chains from its eastern boundary and on the 18th of May we had uncovered some small fractures showing cobalt bloom.

At that period of the camp's development this occurrence of cobalt bloom was considered of more importance as an indication of probable enrichment than was later the case, and as at that time it was necessary to have inspection for discovery by the Ontario Bureau of Mines' representative in order to obtain title to the claim as mining property, I immediately arranged with Mr. E. T. Corkill, at that time mining inspector, for an examination for "discovery." Mr. Corkill accompanied me to the property on the 19th May, and examined the occurrence above referred to and then spent some time with me in a general examination of the claim. At a point on or near the south line of the claim, about where No. 2 shaft was afterwards located, we had built a small log hut and to the west of this there was a "draw" or section of low ground with a general north-south strike. Mr. Corkill expressed the opinion that this probably indicated a line of weakness and suggested the advisability of doing some trenching at this point. He and I put in the stakes for this work and the men started at once. I have always felt that Mr. Corkill's suggestion at that time was primarily responsible for the discovery that led to this property reaching its ultimate success.

That afternoon, after a very small amount of trenching work, the outcrop of what afterwards was known as No. 1 vein was uncovered and consisted of over twelve inches of smaltite and niccolite, afterwards proving on assay to contain little or no silver. When this discovery was reported to me late that evening at Cobalt, I immediately proceeded to the property for the purpose of staking the ground to the south as this discovery was on our south line with a strike approximately northeastward, which would consequently carry the vein into the ground to the south.

On my arrival I found that the claim to the south had been staked by a Mr. Gans on our discovery, his "discovery" post being in our trench and on the vein uncovered by our men. I accordingly staked the claim on the ground that as the discovery had been made by our employees it could not also be a valid "discovery" for one who had no part in the operation. This resulted in litigation as to the title to this additional claim of 20 acres, afterwards known as the "Gans" claim, and necessitated a restaking on our part. Eventually this claim became and now is a part of the Temiskaming mine.

We started a shaft, No. 2, on this vein and in sinking found that the character of the vein matter changed from massive smaltite and niccolite to calcite carrying little or no mineralization. This condition persisted to a depth of 80 feet at which point we started a drift north. There was no change until at a point about 90 feet north of the shaft we encountered a body of very rich ore, a few "rounds" out of which produced about twenty tons and realized about ninety thousand dollars. Encountering this enrichment at this depth was a most fortuitous circumstance, as very few if any of the veins afterwards developed on the property "apexed" as high as this above the diabase sill.

From this point the history of the property is too well known to require comment further than is covered by Mr. Fisher in his report to you.

I should like to add that I consider that the experience of this property, which is now being duplicated in the South Lorrain area, shows that, given proper geological and structural conditions, even in the absence of surface values, there are many opportunities still existing of developing properties of major importance in the diabase-Keewatin and diabase-sedimentary contact in the Cobalt area.

The Early History of the Temiskaming Mine

By NORMAN R. FISHER

Mr. Norman R. Fisher was general manager of the Temiskaming mine until the spring of 1914, and he was consequently familiar with the earlier development of the property. The writer asked Mr. Fisher to give the Ontario Department of Mines an outline of the early history and a description of the ore bodies which were mined up to that time. The Department is much indebted to Mr. Fisher for the following report which is dated January 12th, 1923. The numbering of the veins in the early days does not appear to quite agree with the numbering of the veins as shown on the Department's Beaver-Temiskaming sheet No. 31a-1; nor is the 80-ft. level shown on this sheet.

Though it was not until May, 1907, that silver in payable quantity was discovered at what is now known as the Temiskaming mine, its birth may reasonably be said to have taken place in the year 1906, with the discovery on the surface, during the summer of that year, of two strong calcite veins well bespattered with cobalt bloom and showing at points considerable smaltite, but containing little or no silver either in combined or free form.

Both these veins occurred in the Keewatin formation, which was at the time little favoured by experts for the occurrence of silver, and as a consequence the property might still have remained a mere prospect to this day but for the fact about this time it came under the control of that forceful pioneer of the northern Ontario mining field, Mr. B. E. Cartwright, who in after years

took so prominent a part in and did so much towards the development of that field generally. It was he and his associates who, contrary to all expert advice, decided to prospect them at depth, and by the fall of 1906 had sinking on them both well under way.

At a depth of about 40 feet the work on the more westerly of these two veins, which some eight or nine years later proved to be such a bonanza at depth, was abandoned, not altogether because it was the less promising of the two at the time, but rather because of its being in low ground and so more expensive to explore, and thenceforth all energies were concentrated on the exploration of vein No. 1.

At the point where sinking was commenced on the latter, the vein was some ten inches wide of solid smaltite, with little or no silver content, but this very soon gave way at depth to very barren looking, unmineralized calcite and so continued until it eventually dipped from the shaft at a depth of about 50 feet.

Though lack of courage to proceed farther under such unpromising conditions might in those days have very well been excused, these resolute pioneers decided to keep on with their sinking, and to investigate the vein at still greater depth; and with this end in view eventually ran a crosscut to it some 80 feet below the collar of the shaft.

Where intersected the vein was still found to be a very strong one, some 12 inches wide, but unfortunately still entirely composed of barren calcite, with not even a sign of smaltite or any of its kindred metals in it to encourage farther exploration. Nevertheless, the owners remained steadfast in their resolve to locate the silver which they were still confident existed there, and forthwith decided to further prospect the vein by drifting upon it both ways at this level.

For some time very discouraging results obtained in this work. Nothing was encountered to indicate the near presence of silver. The vein continued both ways as barren-looking calcite, physically weakening towards the south, but gaining in strength towards the north until on May 17th, 1907, after drifting upon it for about 90 feet in the latter direction the miners, upon returning to the face after shooting a round of holes, were astonished to find some 15 inches wide of solid metal glistening before them with native silver sticking out all over it.

The next day, May 18th, is probably still very vivid in the memory of many of the old-timers of the north country because of the great excitement that was created when a large block of this ore was conveyed to Cobalt and publicly displayed to the great wonderment of the crowds who sought to view it, because its discovery under such apparently disadvantageous geological conditions had all along been so little expected.

This rich ore continued in the drift more or less constant in width and values for a length of about 30 feet, when it gave way entirely to barren calcite as suddenly and cleanly as it had come in, and it continued as such until it was decided to stop farther drifting upon it to permit of the ore shoot being mined for an early shipment.

Unfortunately the back stoping on this was not productive of much ore as it was soon discovered that the ore shoot had been encountered very near its apex, even at its highest point only carrying up some 15 or 20 feet above the back of the drift where it again gave way entirely to barren calcite.

Directly above this point the surface was considerably lower than around the shaft, and taking this into consideration I later figured that the top of this ore was about 40 feet from the surface.

After mining out all the ore to be found in this stope, the ore shoot was attacked by underhand stoping, and this work had reached a depth of some 36 feet from the bottom of the drift before the extraction of further ore was for the time being abandoned to permit of the shaft being sunk deeper so that the ore body could be more conveniently mined and its continuance to a greater depth established.

So far the work done upon it showed the ore shoot to be carrying to depth not only very regularly in length but unusually strong in width and constant in value, being in places as much as 37 inches wide of ore, the richness of which may be gauged from the fact that the initial shipment of 52,366 pounds made in May, 1907, gave a return of 123,786 ounces of silver, whilst a further shipment of 82,452 pounds made in August of that year gave a return of 185,178 ounces.

Up to this stage the exploitation of the property had been carried on with very primitive appliances and equipment. This was now replaced by more up-to-date steam-power equipment, and the sinking of the shaft to a farther depth of 100 feet was commenced.

Upon the completion of this a crosscut was run at a depth of about 173 feet to again intersect the vein, and after this had been done the extension of the ore shoot to this level was eventually picked up in it, again as strong and rich as when it had been left behind in the bottom of the winze above.

As soon as possible preparations were made to overhand stope the ore body from this level, and whilst this was going on prospecting for other ore bodies was also carried out.

The first discovery to be made in this search was of a vein some 2 or 3 inches wide, subsequently known as No. 4, which was encountered striking a few degrees north of east some few feet to the north of the ore shoot in No. 1 vein if not actually coinciding with its northern extremity.

Though carrying pay ore this vein was on the whole not nearly so rich as No. 1, being much more irregular in its silver content, and even at that time was noticed to be very different in certain of its physical characteristics, especially in that it occurred very free from the country rock enclosing it whilst No. 1 vein was always found to occur in a more or less frozen condition.

It disappeared towards the west as a mere knife blade crack, so was followed towards the east, and some 70 feet distant No. 2 vein, which together with its subsidiaries, subsequently proved to be probably the greatest producer of the property, was encountered. Striking in a north and south direction this vein was later found to traverse the full length of the property, running more or less parallel to No. 1 vein, and to contain not only well defined and regular chimneys and shoots of ore, but also numerous lenses occurring sporadically throughout it and varying considerably both in extent and richness.

Whilst these lenses had no apparent relationship to each other or any particular geological feature, the chimneys and shoots were plainly influenced in their occurrence by certain factors, the chimneys, which were more or less vertical and in places up to 4 feet wide of over 5,000-ounce ore, being intimately related to a system of cross-fissuring, whilst the horizontal shoots were undoubtedly governed in their occurrence by the Keewatin-diabase contact conditions.

The influence of this east and west system of fissuring on the occurrence of silver in the north and south systems was first noticed at the intersection of the east and west No. 4 vein or fissure with the north and south No. 2 vein, at which point rich ore was found to occur in the latter at the north of the intersection, whilst only barren calcite occurred to the south of it.

The vein was richest, too, at and near this intersection, gradually dwindling to barrenness towards the north as No. 4 vein or fissure was left behind, and thereafter continued as more or less barren calcite until another of these east and west fissures, merely a knife blade in width this time, was encountered. Here ore again came in with as remarkable suddenness and distinctness, only to once more dwindle in value towards the north as this cross-fissuring was also left behind.

Other such shoots or chimneys of ore were later found at similar intersections throughout the mine, and these being not only very persistent in depth but unusually regular in their width and values throughout, really proved to be the main source of production from this property during its active existence. It is significant, however, that though these ore-shoots carried down through the full depth of the Keewatin more or less regular both in length and width and with only an occasional lapse in values, they were never known to pass through the contact into the diabase sill below, though the vein itself, usually as white barren calcite and sometimes as pink calcite, invariably did.

In these veins, however, other ore shoots of the contact variety and apparently influenced in their deposition by the Keewatin-diabase contact were found in both formations. They generally occurred a few feet to one side or the other of the contact, with their longer axes paralleling it, and varied considerably in extent, the largest of them measuring about 80 feet long by about 40 to 50 feet deep of continuous ore, and wholly in the diabase.

These horizontal shoots and the lenses could only be located by intensive exploration at all levels, but the vertical shoots or chimneys of ore once located at any level were always easy to pick up again at any other level because of their intimate relationship to the east and west cross-fissuring before mentioned.

The close connection between this cross-fissuring and the existence of the chief ore bodies of the property was, in fact, very obvious almost from the beginning. As a result they were, during the seven years of my régime at any rate, looked upon and known about the mine as the feeders of the north and south vein-systems, and the exploration and development of the property was carried out with this feature in mind, accompanied, it may be added, with most satisfactory results.

Of the two veins originally discovered on the surface of this property and described at the beginning of this article, I have so far given the history of only vein No. 1, but it is also of interest to note that the other, upon which the 40-foot prospect shaft was sunk in the earliest stage of the property's development, only to be then temporarily abandoned for the certain good reasons already given, later proved to be just as important a producer, if not the greater of the two.

This vein was first investigated underground from a crosscut at the 173-foot level, but where intersected at this horizon appeared to be of very little importance. It was, however, later cross-cut to at the 270-foot level and intersected almost directly below where it was first investigated by the prospect shaft at the surface, and here found to be of considerable promise, containing, it is true, an inappreciable quantity of silver, but considerable smaltite and niccolite, particularly the latter, up to 9 inches wide. Indeed, so ripe-looking and promising did the vein appear to be at this point that it was given particular notice in the annual report of that year, and the prognostication was ventured that an ore shoot would sooner or later be picked up in it. It was with every expectation of this that two crosscuts were actually being run to it from the 499-foot level in the spring of 1914, when the writer retired from the general management of the property.

I have since learned that these crosscuts were later extended to tap this vein and actually encountered extremely rich ores where they intersected it, but owing to my departure I am not sufficiently conversant with the extent or richness of this ore body nor of the exact conditions under which it was found to be able now to give any authentic information regarding the same.

One other point, it is perhaps interesting to note respecting the occurrence of the ore bodies of this property, is that in the passage towards the silver the sequence in the occurrence of the vein matter was usually found to be the same at all points whether near the surface or deep underground.

Except of course where silver was encountered direct, as at the intersection of the above-mentioned cross-fissuring, the usual order was, first, smaltite in varying quantity, then, barren calcite, and when niccolite began to come, silver was always expected to appear in the next round or two of shots and usually did when this condition arose within the silver-bearing portion of the property.

The silver encountered would of course vary considerably in extent and would sometimes be associated with a predominance of niccolite, or one of its allied minerals, but usually these would soon give way to a predominance of smaltite.

In other words, whilst smaltite was usually the forerunner of the occurrence of silver, and was also generally the chief mineral intimately associated with the main mass of it, niccolite or one of its allied minerals generally predominated on the fringe of its occurrence, and when encountered in a vein existing under otherwise favourable conditions for the occurrence of silver, was always looked upon as an almost sure indicator of the near presence of silver.

Description of Temiskaming Mine Workings

The following is a brief description of the various levels of the Temiskaming mine, commencing with the lowest.

In mapping the contact between the Keewatin and the Nipissing diabase, the plans published by the company in the special report to the shareholders in 1918 have been of assistance. The contacts on the Department's maps agree, approximately, with those on the company's maps. The company furnished the writer with plans showing the location of the veins on the various levels.

1,600-ft. Level.—This level was full of water at the time of our examination, and was consequently inaccessible. The information shown on the plan was obtained from the special report in 1918 of the Temiskaming Mining Company, and partly from a geological plan furnished by Mr. Wm. Cooper, mine superintendent. It is reported that a non-productive vein was discovered striking north and south. The vein was said to occur in a fault which showed a few inches of fault breccia. The vein material in the fault was said to occur sparingly and irregularly in the fault. It has been followed by a drift for about 850 feet, and appears to be the same vein in which the Beaver is reported to have found 40,000 or 50,000 ounces of silver on the 1,600-ft. level.

The workings are in Nipissing diabase and in the Keewatin series.

About 150 feet above the 1,600-ft. level, in the shaft, there is reported to be a shear zone.¹

1,130-ft. Level.—A station has been cut at this level; the rock is Nipissing diabase.

830-ft. Level.—This level has only 150 feet of workings, all in Nipissing diabase. The coloured section opposite page 10 shows a raise from this level to the level above, namely, the 749-ft.

749-ft. Level.—The veins on this level consist mostly of white calcite, and subordinately of pink calcite. They all dip steeply to the westward, and are in the Nipissing diabase. The veins are smaller on this level than the veins on the levels above.

649-ft. Level.—This level is also all in Nipissing diabase, the most easterly crosscut, however, shows the diabase gradually becoming finer in grain, suggesting that the Keewatin rocks are not far east of the face of the crosscut. The veins also dip to the west, as in the level below, following joint planes in the diabase. In the long crosscut westward of the shaft, there is a flat fault showing fault breccia and gouge an inch or two in width.

573-ft. Level.—This level shows how the veins pass from the Nipissing diabase into the Keewatin rocks. There is a long crosscut extending over 800 feet east of the shaft to the east boundary of the property. This crosscut went through the chert formation and showed it to have a width of about 175 feet. The Keewatin rocks immediately west of the chert formation are impregnated with iron pyrites for a width of 100 feet, and the walls of the crosscut in this iron-pyrites zone are rusty, owing to the decomposition of the sulphide. In the

¹Special Report to Shareholders, Temiskaming Mining Company, Limited, 1918.

same crosscut east of the chert formation, there is a lamprophyre dike dipping 18° to the northeast. As on the levels below, so also on this level the veins in the Nipissing diabase dip steeply westward.

499-ft. Level.—This is the most extensive level in the mine, the workings extending from the north boundary almost to the south, a distance of nearly 1,800 feet.

Vein No. 19, at the northwest end of the property, was an important producer. It is the southward extension of No. 3 on the Beaver. The vein was followed for over 500 feet south of the Beaver boundary, but the ore-shoot continued for only about 190 feet south of the boundary. It is stated that the silver content of the vein suddenly disappeared, although the calcite vein continued to the south. The writer is not able to account for the sudden disappearance of this ore-shoot.

Vein No. 20 is a strong pink calcite vein; it occurs in a fault which has about a foot of fault breccia.

At the northeast end of the mine, veins No. 6 and No. 3 are in chert. Some low-grade mill-rock occurred in the chert.

Vein No. 506 is in the southeast part of the Gans. It about parallels the north and south co-ordinate line 500, and lies between the east and west co-ordinate lines 1,100 and 1,500. The company did not apparently keep a record

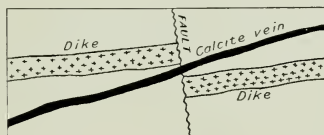


Fig. 29—Sketch showing relation between feldspar-porphyry dike, fault, and calcite vein; 499-ft. level, Temiskaming mine. The vein is two to three inches wide, and is clearly younger than the dike or fault.

of the silver output of the vein, but the writer was informed it produced about 10,000 ounces of silver. The vein gave promise of an important output, but its exploration proved disappointing. The vein consists mostly of white calcite up to eight inches wide, possibly averaging three or four inches. In one place niccolite makes up half of the vein. In the stope a narrow dike of pink feldspar-porphyry cuts the Keewatin. The dike has been faulted about six inches. The vein cuts about at right angles across the fault (Fig. 29), but the vein is not faulted. This appears to be a clear case in which it is proved that a vein is younger than a fault.

At the southeast corner of the workings, a vein has been followed for about 350 feet, and a little stoping has been done. The vein where examined consisted of calcite two or three inches wide. Near the vein some narrow granite dikes cut the Keewatin. These dikes no doubt come from the granite mass a short distance to the east.

385-ft. Level.—This level is almost wholly in Keewatin rocks, although the diabase has been intersected in three short crosscuts at the west side of the workings. Minor faulting, indicated by gouge and fault breccia a few inches wide, has taken place at or near the contact of the Keewatin and diabase. The crosscut at the northeast corner of the level has intersected the chert formation and shows it to have a width of about 200 feet. About the central part of the level there is a fresh basalt dike, 12 or 15 inches wide, cutting the Keewatin rocks

and dipping about 70° to the southwest; the relationship of the dike to the veins was not definitely determined, but the dike appeared to be younger than the veins. In raise No. 402, about 90 feet above the level, the dike appears to cut a calcite vein.

350-ft. Level.—This level is not connected with the main shaft; it is reached by a raise from the 270-ft. level. Very little work, comparatively speaking, has been done.

270-ft. Level.—The workings are all in Keewatin cut by lamprophyre dikes of Haileyburian age. The chert bed was not intersected, but its probable position is shown on the plan. Vein No. 17 occurs in a fault, showing fault breccia four or five inches wide, and gouge fractions of an inch wide.

226-ft. Level.—Also all in Keewatin rock; the probable position of the chert bed is indicated on the plan.

173-ft. Level.—The level is in Keewatin; the long eastward crosscut intersects the chert bed for about 75 feet. The basalt west of the chert is sparingly impregnated with iron pyrites for about 150 feet.

90-ft. Level.—This level is not shown on the plans. At the time of our examination of the level, during August 1920, the stope was about 350 feet long and the ore was reported to run from 6 to 22 ounces of silver per ton. The stope was broken through to the surface in one place. In places there are two quartz veins, more or less parallel.

These quartz veins appear to have been opened up and fractured, allowing the calcite to be introduced later into them. Fragments of quartz appear in the calcite. In places the quartz is banded and the calcite cuts across the banding of the quartz; in other places there is no quartz in the vein. On the west wall of the stope, a few feet west of the vein-system, there is gouge and fault breccia a few inches wide; on the gouge there are pronounced scratches dipping 20° to 30° to the south.

TRETHEWEY (CONIAGAS)

The Trethewey was purchased by the Coniagas Mines, Limited, in January, 1920, for \$100,000. Prior to that time the property produced 6,761,581 ounces of silver and paid \$1,211,999 in dividends.

In respect to the veins, the property may be divided into two parts, one at the northeast corner and one at the southeast. The latter is the more important, the vein-system there being the westward extension of the Meyer system on the Nipissing and the northward extension of certain veins on the Coniagas. The "main" vein on the Trethewey is the westward extension of the Meyer vein on the Nipissing. The productive area at the southeast corner of the Trethewey is only about eight acres in extent. The veins at the northeast corner of the claim are southward extensions of veins on the Hudson Bay; they are worked from No. 4 shaft.

The stope section of the main vein is shown on the vertical section on page 9.

The largest stopes on the property are on the "main" vein, and on the extension into the Trethewey, of one of the Coniagas veins, No. 2. These stopes are thirty or forty feet wide in places.

As on the Coniagas, Buffalo, and Townsite, so also on the Trethewey there is a fault which is roughly parallel to the contact between the Keewatin and the Cobalt series. On the first level the fault is found entirely in the Cobalt series, but in the lower part of the mine the dip of the fault becomes steeper, and it passes into the Keewatin series. It has not been traced quite down to the third level, but was found in a sub-level above the second level, and on the second

level. This fault has been called the Trethewey fault on the plan of the first level, while on the sub-level referred to, it is called the "reverse" fault. It is probably continuous with the Coniagas fault. On this sub-level the Keewatin has been thrust on top of the Cobalt series, proving that the fault is a reverse one, the displacement of which is at least 15 feet (section facing page 8).

The sediments of the Cobalt series on the Trethewey are not as thick as they are on the Coniagas, nor does the bed of slate-like greywacké, which is well developed on the 150-ft. level of the Coniagas, extend into the Trethewey.

Trethewey Mine Workings

Third Level.—(No. 2 shaft, elevation above sea level 900 feet.) The third level is a small one at the southeast corner of the mine with some 700 feet of workings. About a third of the workings are in the Keewatin series, the remainder in conglomerate and greywacké of the Cobalt series. The contact between the Keewatin and Cobalt series may be seen in a crosscut; the contact is sharp and well defined.

There is no sign of the Trethewey fault to be seen on this level, probably because the fault has passed into the Keewatin below the level. The workings do not appear to have extended far enough to the northwest to have encountered it.

Second Level.—(No. 2 shaft, elevation above sea level 945 feet.) The second level at the southeast corner of the property has encountered the Keewatin series in four places. In one of these places a lamprophyre dike cuts the Keewatin; a granite boulder of the Cobalt series about three feet wide was found resting directly on the lamprophyre dike. Evidently the contact between the conglomerate and the old basement is sharply defined here. In No. 6 shaft the contact between the Keewatin and the conglomerate of the Cobalt series occurs about 15 feet above the second level. The Keewatin here consists of a fine-grained grey slate resting in almost vertical attitude. This bed of Keewatin slate is exposed on the surface along the shores of the deep bay of Sasaginaga lake, westward from No. 6 shaft.

Sub-levels between the First and Second Levels.—The sub-levels form a complex group of workings which were somewhat difficult to map in a satisfactory manner. A composite plan of the sub-levels will be found on the Trethewey sheet, together with separate geological plans of each sub-level. On the sub-level, the elevation of which is 970 feet, the plan shows a "reverse" fault. This is probably the Trethewey fault; it is a reverse fault with a displacement of at least 15 feet. The Keewatin has been thrust on top of the Cobalt series.

First Level.—(No. 2 shaft, elevation above sea level 1,021 feet.) The Trethewey fault has been traced for about 700 feet. It may be studied in daylight in the open cut at No. 1 shaft. The fault has a fault breccia two or three feet wide in the first crosscut south of No. 5 shaft. In the open cut referred to the fault splits, the upper part following the bedding and the lower part cutting across the bedding.

No. 6 shaft, about the middle of the property, was sunk on a vertical "mud seam", or fault, with fault breccia and gouge one-half or three-quarters of an inch wide. In one or two places it is two inches wide. The fault on the first level has been drifted on for about 250 feet. No. 6 shaft was sunk on this fault to the second level where a pink calcite vein, an inch or two wide, was found in the fault.

At the northeast corner of the property certain veins are worked from No. 4 shaft. These veins were not of great importance and the stopes were all small.

HUDSON BAY

The Hudson Bay Mines, Limited, has a capital of \$3,500,000 in shares of a par value of \$5.00 each. Of this, \$3,200,000 have been issued. The property north of the Trethewey mine has produced 6,405,938 ounces of silver and has paid \$778,909 in dividends to the end of the year 1922.

The productive part consists of a small area in the southeast corner of the property.

There are two important veins, namely, No. 2 and No. 1, the locations of which are shown on the fourth level. The plans do not give the numbers on the higher levels. The No. 1 vein strikes a little north of west and occurs immediately south of the main shaft. No. 2 vein passes into the Nipissing and is known as No. 64 on that property.

Other veins occur, but the two referred to are the most important producers of silver.

No. 1 vein has been explored in the Keewatin to a depth of over a hundred feet, and it has still a width of one to eight inches of barren calcite. An interesting feature regarding this vein, where it occurs in the Keewatin, is that it follows the dip and strike of a bed of Keewatin chert and slate commonly called "iron formation." Evidently this fundamental structure in the Keewatin formation constituted a line of weakness along which the vein fracture formed, and these fractures extended upwards into the Cobalt series. The overlying sediments of the Cobalt series may have had little or nothing to do with the guidance of the fracture. Certain veins in the Foster, Buffalo, and other mines were also found to follow the strike and dip of similar almost vertical beds of Keewatin chert or slate, known as "iron formation."

On the surface of the Hudson Bay property the "iron formation" and lava flows of the Keewatin series may be worked out. The Keewatin consists of three or four beds of sediments interbedded with basaltic lava flows. The sediments strike a little south of east and dip steeply to the southward. They consist of chert and slate. It is one of these beds of sediments which the No. 1 vein follows where it has been explored in the Keewatin.

It was stated by the management that veins Nos. 1 and 2 were the only ones that produced important quantities of mill-rock. The stopes of these veins are wide, in places 15 to 40 feet. The other veins yielded mill-rock for only two or three feet on each side of the veins.

There are three almost vertical faults, striking southeastward and dipping steeply to the southwestward. The best known one is No. 64. The others, known as Z and Y, are north of No. 64, and they appear gradually to join No. 64 on the Nipissing. Faults Z and Y are shown on the third level of the Hudson Bay. Comparatively little silver occurs to the north of these faults. The question arises as to what influence the faults had on the deposition of the silver. It is possible that the faults acted as a barrier or dam to the silver solutions, preventing the latter from depositing silver north of the faults. This idea, however, is merely a suggestion; but whatever may have been the cause, the fact remains that little silver has been found to the north of these faults, on the Hudson Bay, Nipissing, Chambers-Ferland, O'Brien, or Violet. It must be admitted, however, that the rocks north of the fault have not been intensively prospected by underground workings.

No. 2 vein on the fourth level occurs in fault No. 64. This fault is evidently older than the vein. The other two faults, Z and Y, contain calcite in places.

In addition to the three faults mentioned, there is another fault dipping southeastward which follows in a general way the contact between the Keewatin

and Cobalt series. This fault probably corresponds to the Trethewey and Coniagas fault which is known as the "contact" fault. It occurs also on the Buffalo, Townsite, and City properties.

Below will be found a brief description of the various levels of the Hudson Bay, beginning with the lowest.

Hudson Bay Mine Workings

Fifth Level.—(Elevation above sea level 797 feet.) The fifth level is reached by means of a winze from the fourth. This winze is located at the southeast corner of the property on vein No. 2, about 15 feet from the Nipissing boundary. The level and winze were full of water at the time of examination, but, judging from the dip of the Keewatin floor, it is probable that the Keewatin occurs some 10 feet or more below the fourth level. Thus, the fifth level is probably entirely in Keewatin.

Fourth Level.—(Elevation above sea level 847 feet.) No. 1 vein has been explored in the Keewatin on this level in the drift. It is a strong vein from one to six or eight inches wide, and it has been stoped in places. The interesting thing about this vein in the Keewatin is that it follows a bed of chert and slate known as Keewatin "iron formation", the bed being in an almost vertical position. On levels above, this vein also follows the bed of "iron formation."

At the east end of No. 2 vein, at the winze from the fourth to the fifth level, fault No. 64 was met with. The fault consists of a foot or two of fault breccia and gouge. The relation between the fault and No. 2 vein may be seen on the east face of the workings. The vein may be seen to come down vertically to the fault, which dips at an angle of 70° or 80° to the south. As the vein approaches the fault it also begins to dip to the south and finally follows the fault down. The winze being full of water we were not able to observe if the vein followed the fault down to the fifth level, but it was stated by the management that such was the case.

The "contact" fault was found occupying its usual position near the contact between the Cobalt and Keewatin series.

The Cobalt series on this level consists of conglomerate. Owing to a printer's error, the rock is incorrectly shown as slate-like greywacké on the plan of the fourth level.

Third Level.—(Elevation above sea level 896 feet.) No. 1 vein occurs immediately south of the main shaft. It has been followed for about 200 feet in the bed of Keewatin "iron formation" referred to in the level below. For some distance, the vein conforms in strike and dip to the "iron formation." The vein in the "iron formation" averages about an inch or two of barren calcite. It may still be seen on the northwest face of the drift.

This level is characterized by the occurrence of three vertical or steeply dipping faults, which on the plan have been named No. "64," Y, and Z. The faults consist of the usual fault breccia from an inch or two to as much as three or four feet in width. Here and there a calcite vein occurs in them, and they have been stoped to a limited extent. Some iron pyrites was noted in them.

Fault "No. 64" is almost vertical, striking about 18° north of west. It varies in width, being as wide as two feet in places, and consists of crushed rock and gouge. There were vugs of calcite in the fault. It is rusty in places owing to the decomposition of iron pyrites. A calcite vein of irregular width, and not continuous, follows the vein. The south branch of the fault enters the large stope in vein No. 2, but, as this vein was mined out, we could not determine the relation between the vein and fault on this level.

Fault Y strikes about west 50° north; at one place it dips 80° to the south-westward, while at the north end it dips 67° to the northeast. It has been stoped in places, and was said to carry small quantities of native silver. The fault consists of a fault breccia and gouge as wide as three feet; calcite cements together the rock fragments. In places almost pure pyrite forms a vein in the fault as wide as three inches and the pyrite is beautifully banded, as many as a dozen or more parallel bands occurring.

Fault Z strikes about west 32° north, and the southeast part was accessible. It consists of a fault breccia and gouge from an inch to 12 inches wide, and a calcite vein one to two inches wide occurs in it. Cobalt bloom was noted in the calcite vein in places.

There is no slate-like greywacké on this level save a few inches at the south-west part of the workings. Here the "contact" fault follows the bed for some distance.

A crosscut 660 feet long runs north along the east boundary. It is blocked by a concrete dam and we were not able to examine it, but the management reports it to be all in conglomerate of the Cobalt series.

Second Level.—(Elevation above sea level 948 feet.) The No. 1 vein occurs immediately south of the main shaft. It strikes a few degrees north of west. It has been followed for 180 feet west of the main shaft; as on the levels below it follows the same bed of Keewatin "iron formation." The vein where it occurs in the "iron formation" is from one to four inches wide.

This level shows how vein No. 1 and vein No. 2 are related to each other. Vein No. 2 strikes a little south of west for about 230 feet and runs into vein No. 1 almost at right angles. The last 50 or 75 feet of No. 2 vein, before it enters No. 1 vein, is not yet stoped out. The vein may be seen in the back where it is a strong one consisting of three to eight inches of pink calcite.

Fault No. 64 has been explored on this level in a drift which follows the fault continuously for 190 feet. In this drift it may be seen that the fault has a width of as much as six feet, consisting of a fault breccia and gouge. No calcite vein was noted, although there are some irregular stringers of calcite. At the east end of the drift a bed of finely-banded greywacké about three feet thick has been faulted by fault No. 64. The rock on the south side is the downthrow side. The bed of greywacké dips gently westward.

In one place on the level a vein of calcite one-quarter to one-half inch in width passed through fault No. 64 without being faulted. It is evident that this small vein is younger than the fault.

First Level.—(Elevation above sea level 981 feet.) Fault No. 64 was drifted on for about 190 feet and found to be similar in character to its deeper parts on lower levels. The bed of slate-like greywacké is also faulted in a similar manner to that noted on the second level. The rocks on the south side of the fault appear to have been faulted down about 10 feet.

At the northwest corner of the workings there is a vein called "vein blank"; it is north of fault No. 64. This vein has been stoped from the first level to the surface, but the company reported that it was not a very profitable vein. This is one of the few ore bodies which occur north of fault No. 64. On the O'Brien and Violet some ore was also found north of this fault.

No. 1 vein passes into the Keewatin "iron formation" as on lower levels.

The contact between the "iron formation" and the conglomerate of the Cobalt series is as sharply defined as a knife.

BEAVER CONSOLIDATED

The Beaver Consolidated Mines, Limited, has an authorized and issued capital of \$2,000,000 in shares of the par value of \$1.00. The mine has produced 6,031,448 ounces of silver, and had paid \$710,000 in dividends. There are about 8.5 miles of underground workings, including drifts, crosscuts, winzes, raises, and shafts. The company ceased operations on the 31st of December, 1920, but the property was leased by the Coniagas, which company began operations in January, 1923.

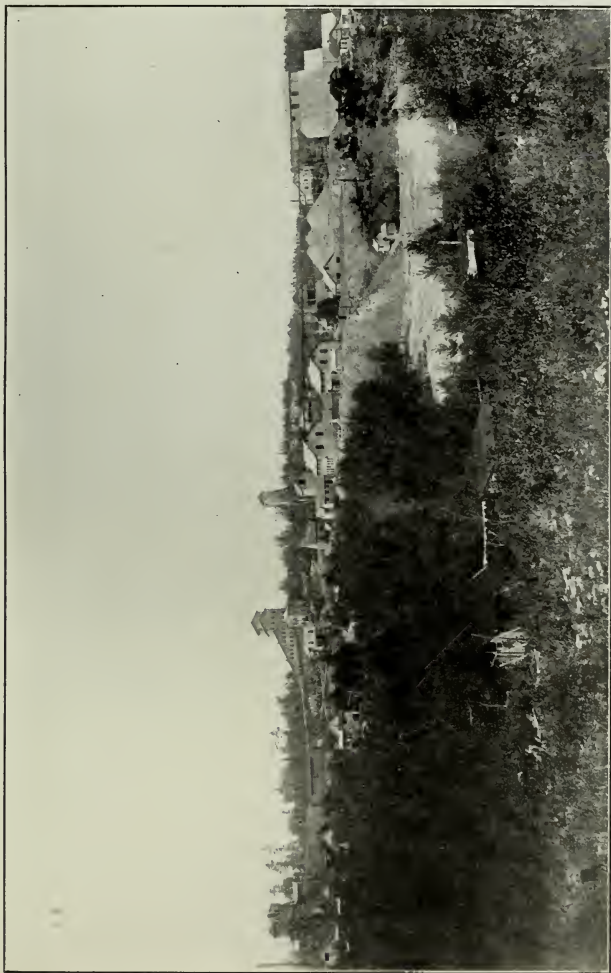


Fig. 30—Temiskaming and Beaver mines.

According to the annual report of the Beaver company for the year ending February 28th, 1919, the Beaver owned approximately seven-eighths of the capital stock of the Kirkland Lake Gold Mining Company, Limited, at Kirkland Lake, Ontario, which the Beaver purchased at a cost of \$370,957.79.

The Beaver vein-system is the northward extension of the Temiskaming system, which property is contiguous to the Beaver on the south.

The silver ore at the Beaver occurs almost wholly at the top of the Nipissing diabase sill (vertical sections facing page 10). It is reported, however, by the Beaver management that 40,000 or 50,000 ounces of silver were obtained below the diabase sill on the 1,600-ft. level. This is the greatest depth below the surface at which silver ore has been found at Cobalt and is of interest for that reason. The remainder of the silver was mined above the 804-ft. level.

Regarding the occurrence of silver ore on the 1,600-foot level of the Beaver, the Ontario Department of Mines is indebted to F. L. Culver for the following information contained in a letter dated May 25th, 1921: "I am sorry that we did not keep an actual record of what was taken from the 1,600-foot level. However, I would say that it was possibly 40,000 or 50,000 ounces [of silver], but, assuming that you desire this for statistical purposes, I could not vouch as to the accuracy. I know we took out some high-grade and milled a lot of the product."

The central zone of the diabase sill at the Beaver or Temiskaming has not yet proved to be productive.

The management of the Beaver estimate that about three-quarters of the ore was obtained from within about 125 or 150 feet of the contact between the top of the Nipissing diabase sill and the Keewatin, the Keewatin being much more productive than the diabase. A little of the ore extended down into the sill to a depth of 275 feet, at which depth the veins became barren and narrower. The veins passed from the Keewatin down into the diabase without pinching out.

There are two main veins at the Beaver known as No. 3 and No. 5. These veins have an average strike of about north 22° east, and they extend southward into the Temiskaming. The two veins are parallel and are about 225 feet apart. Other veins occur, but these are the most important ones. The veins where they occur in the Keewatin dip steeply to the eastward, but about where they enter the top of the Nipissing diabase sill they become vertical, and, finally, in the sill itself, they dip steeply to the westward. The coloured section opposite page 10 shows the stoped parts of vein No. 5 on the Beaver, and of veins Nos. 1 and 3 on the Temiskaming.

While the veins at the top of the sill have an average strike of north 22° east, the vein which produced ore at the bottom of the sill strikes north 30° west, or about at an angle of 52° to veins at the top of the sill. None of the veins at the Beaver or Temiskaming have been followed downward continuously from the upper part of the diabase sill to the bottom of the sill.

The stopes at the Beaver, and also at the Temiskaming, are narrow compared with many stopes elsewhere in Cobalt which occur in the conglomerate, greywacké, and slate-like greywacké of the Cobalt series. This is due to the fact that the Keewatin basalt at the Beaver and Temiskaming did not fracture along the wall rock of the veins into innumerable tiny cracks. Hence the silver minerals did not penetrate far into the wall rock. The rocks of the Cobalt series, on the other hand, have generally been fractured more readily than the Keewatin rocks; hence the silver minerals were able to penetrate farther into the rock.

Owing to the irregular and erratic occurrence of the ore-shoots in the veins, the Beaver management did not publish in their annual reports a statement regarding the ore blocked out. At the time the property closed down, in December, 1920, it was stated that there were 14,000 tons of broken ore in the mine.

The ore-shoots of the Beaver are terminated at the north end of the property by a fault which strikes northwestward and dips steeply to the northeast. No ore occurs north of the fault. This fault is older than the period of ore deposition, because ore occurs in the fault; and some of the richest ore in the mine is said to have been mined from this fault, known as the Beaver fault. It is a most interesting, though unfortunate fact that the Beaver fault should limit the ore in a northerly direction on the property. Some veins extend to the north of the fault, but they are not productive of silver. Possibly the fault acted as an impermeable barrier and prevented the silver solutions from penetrating beyond it.

In examining the Beaver and Temiskaming workings, one is struck by the number of barren calcite veins; one is also impressed by the more or less erratic occurrence of ore-shoots in some of the productive veins.

The economic geology at the Beaver and Temiskaming mine has to do with but two main series, namely, the Keewatin and the Nipissing diabase sill. There are also lamprophyre dikes cutting the Keewatin. The Nipissing diabase sill intersects the Keewatin series; and the top and bottom of the sill have been encountered in the workings at depth. The Keewatin consists of basaltic lava flows with which is interbedded a bed of so-called "iron formation" resting in about vertical attitude. This bed consists of cherty rocks and greywacké, finely banded, and will be referred to as the chert bed. It pinches out at the north part of the Beaver and has a maximum thickness of 150 feet at the south end, where it continues southward into the Temiskaming property.

The rock along the west side of the chert formation is more or less impregnated with iron pyrites, some of it, as on the 297-ft. level, occurring in roundish or cylindrical forms.

The chert bed is of little economic interest, except that in places, where it is cut by productive veins, the rock has become impregnated with thin films of native silver. This is owing to the fact that the chert fractured into innumerable cracks, and where the productive veins intersected the chert bed the native silver had a tendency to impregnate the chert along the tiny cracks, and thus to cause the stopes to be wider in the chert bed than they are in the basalt. The basalt did not fracture into the innumerable cracks which are found in the chert. Unfortunately the productive veins in the Beaver occur for the most part in the basalt and the Nipissing diabase. In the Temiskaming the productive veins scarcely touch the chert formation.

Owing to the enterprising management of the Beaver mine, the main shaft was sunk to a depth of 1,600 feet, so that it passed through the entire thickness of the Nipissing diabase sill and encountered the Keewatin series below the sill. The object of this deep work was to prospect the rock below the bottom of the sill. The shaft cut the top of the sill at a depth of about 468 feet, and cut the bottom of the sill at a depth of about 1,590 feet. Allowing for the dip of the sill, it may be estimated that the sill has a thickness of about 1,000 feet, in round numbers. About 1,900 feet of development work was done on the 1,600-ft. level of the Beaver mine, but, unfortunately, at the time of our examination this level was flooded and we were not able to investigate it. If the level were accessible, it would be interesting to find out if the chert formation is vertically below where

it occurs on the top of the sill. By means of this chert formation it would be possible to show what movement, if any, had taken place between the hanging wall and footwall of the diabase sill.

An interesting feature of the geological structure of the Beaver mine is that it has been possible to prove that the diabase sill moved, during its intrusion, from the southeast to the northwest. This is shown by the inclusion of a great block of Lorrain granite, which was found at the top of the sill on the 456-ft. level. The granite inclusion is similar to the Lorrain granite which occurs about one-quarter of a mile southeast of the Beaver mine. As the sill moved towards the northwest it caught up this block of Lorrain granite.

The general structure of the rock formations at the Beaver is shown by the two vertical sections AA and BB, opposite page 32. It may be seen from these sections how the Nipissing diabase sill intersects the Keewatin chert formation and the basalt. The chert formation must occur somewhere below the diabase sill, but, as previously stated, the workings which may show its location on the 1,600-ft. level were not accessible at the time of our examination, so that we were not able to locate it. The vertical sections show its supposed position below the sill.

Commencing with the lowest level, the 1,600-ft., the various levels of the Beaver mine may now be briefly described.

Beaver Mine Workings

1,600-ft. Level.—At the time of our examination of the Beaver in June, 1920, the 1,600-ft. level was flooded and no examination could be made. The plans furnished by the company show that about 1,900 feet of development work had been done. It is stated that the bottom of the Nipissing diabase sill was encountered in the shaft about ten feet above this level, that is, at a depth of 1,590 feet.

The work on this level resulted in the discovery of a vein which is said to be six to eight inches in width. The vein is reported to contain native silver; and it is also stated that leaf silver is scattered through the wall-rock for a distance of about four feet on each side of the vein.¹ A little stoping was done on this vein, and about 40,000 to 50,000 ounces of silver were reported to have been obtained. A winze was put down on the vein to a depth of about 40 feet, and it was stated that high-grade ore was met with. While these results were encouraging because they showed that high-grade ore occurred at this depth, the work did not, however, disclose the presence of commercial ore of importance.

At this depth, namely, 1,600 feet, is the deepest zone in which silver has been found in the Cobalt camp; it is interesting to quote, concerning the discovery, from the company's annual report.

The past year has brought most interesting changes to your mine. A very important discovery has been made—the discovery of high-grade ore at a depth of 1,600 feet. We might mention that this is the lowest depth at which values have been found in the Cobalt camp. A year ago the main shaft had reached a depth of 1,400 feet. During the year the shaft was continued to the lower contact [of the Nipissing diabase sill], the station cut at the 1,600-foot level, and crosscutting both east and west of the shaft uncovered a number of veins.

Drifting on the vein west of the shaft brought us into silver values. This vein is from six to eight inches wide, rich in silver, and on both sides of the vein for a distance of about four feet the wall-rock is heavily impregnated with leaf silver. The discovery of ore at the 1,600-foot level of your property has caused a great deal of interest in the Cobalt camp, and while we are not yet in a position to say to the shareholders that it will actually make a new mine out of the Beaver, it is most encouraging.

¹Annual Report, Beaver Mine, for year ending February 28th, 1917, p. 4.

1,400-ft. Level.—Fortunately this level was being worked at the time of our examination. It was the deepest level in the Cobalt area to which we had access. There are only 800 feet of development work, but enough was done to discover a strong vein at a distance of 500 feet west of the shaft. This vein, which occurs in the Keewatin below the Nipissing diabase sill, was followed for 225 feet and found to strike about north 30° west, with a steep dip to the east. It may be noted that its strike is at an angle of about 52° to the strike of the productive Beaver and Temiskaming veins which occur on the upper contact of the Nipissing diabase sill.

A raise was driven on the vein to a height of some 87 feet above the level, disclosing some niccolite and smaltite; but no silver was encountered, and the vein was still in the Keewatin greenstone. On the level the vein pinches and swells and varies from less than an inch in width up to eight inches or more. It consists mostly of pink calcite together with a little quartz. In places some almost pure smaltite occurs four or five inches in width, and it is reported that smaltite had been found as wide as a foot. The vein evidently occurs in a fault, because four or five inches of fault breccia and gouge occur on the walls of the vein, especially at the northwest part.

The vein occurs partly on the Beaver and partly on the Prince, contiguous on the west to the Beaver. The Prince is under option to the Beaver.

This vein on the 1,400-ft. level is thought to be the upward extension of the vein on the 1,600-ft. level in which a little ore had been discovered, as described in preceding paragraphs.

The crosscut on the 1,400-ft. level runs west for about 600 feet, extending into the Prince property for about 75 feet. The first 400 feet of the crosscut is Nipissing diabase, the remaining westward part being Keewatin basalt cut by lamprophyre dikes, and, at the west end, a very tough, medium-grained hornblende-diabase, probably of Haileyburian age. This hornblende-diabase was difficult to drill.

1,200-ft. Level.—A station is cut at this depth. The rock is Nipissing diabase.

900-ft. Level.—A station has also been cut at this depth, and the rock is likewise Nipissing diabase.

804-ft. Level.—The veins on this level are narrow, varying from about one-quarter of an inch to two inches and probably averaging less than an inch in width. They consist mostly of white calcite, and subordinately of pink calcite. The level is all in Nipissing diabase, and the veins occupy joint cracks. This is the lowest level on which ore is reported to occur in the Beaver at the top of the sill, some stoping having been done on No. 3 vein.

702-ft. Level.—A striking feature of this level is the manner in which the veins occupy joint planes dipping steeply to the westward. The level is all Nipissing diabase.

602-ft. Level.—This level is also completely in the Nipissing diabase sill. The joint planes in the diabase are very regular, and it is clear that the veins occupy the joint planes. The veins dip steeply westward.

530-ft. Level.—With the exception of the southeast part, all of the level is in Nipissing diabase. At the southeast corner the Keewatin has been met with and also the bed of finely-bedded chert (section BB, page 32). The cherty bed is impregnated with thin films or leaves of native silver near veins.

The discovery of the No. 3 vein (No. 19 on the Temiskaming) on this level is described in the annual report of the Temiskaming Mining Company for the

year ending December 31st, 1914, on page 7. In view of its importance we may quote in detail regarding it. Mr. F. L. Culver, the general manager, in that report stated:—

A few months ago, the management of the Beaver Consolidated started to drive a crosscut on the 530-foot level west to locate a vein which they had in early workings in levels above. About 130 feet from their shaft, they ran into a vein of high-grade ore in virgin territory. This vein was intercepted at a point about 55 feet north of the Temiskaming line. Arrangements were immediately made and a contract entered into with the management of the Beaver Company to drive south on this vein into the Temiskaming ground to see if the ore body carried there. The contract provides that, as soon as work commenced on the Temiskaming, the Beaver Company would receive sixteen dollars a lineal foot for drifting and nine dollars a cubic yard for stoping, all ore and waste to be returned through the Beaver shaft to the Temiskaming property. The Temiskaming boundary was reached in December and it has proven that this ore body continues into the Temiskaming ground [where the vein is known as No. 19]. The vein, which has been drifted on for a distance of about 60 feet, is from four to five inches in width carrying very rich ore. A number of tons of ore have been extracted so far which will carry values anywhere from 4,000 to 10,000 ounces of silver to the ton. The Beaver management have since proven that the ore in this same vein extends up to the 456-foot and the 396-foot levels of their property with a width of six to seven inches of very high-grade ore.

The 530-ft. is the lowest level on which the Beaver fault has been met with, the workings below this level not having been extended far enough northeastward to cut it.

The Beaver fault occurs at the northeast corner of the workings and has been followed for 210 feet. In this drift the fault breccia and gouge have a combined width of one to fifteen inches. In places the fault breccia (crushed wall-rock) is as wide as five feet, and along the wider crushed parts the rock in the back of the drift falls off very readily and is therefore dangerous ground to work in. There is a calcite vein from a fraction of an inch to one and a half inches in width in the fault, but the vein pinches out in places. No. 5 vein is a long one, extending from the south boundary of the Beaver northeastward about 575 feet. It extended up to the Beaver fault, and into the fault breccia, where it broke up into stringers. The Beaver fault appears to be older than the No. 5 vein.

About 270 feet east of the shaft, there is a barren vein consisting of many parallel stringers of quartz and calcite from an eighth of an inch to three or four inches in width, the combined width of the stringers being more than two feet.

456-ft. Level.—This level and the one above have the most extensive workings in the mine. About a third of the workings are in Nipissing diabase, the remainder being in Keewatin rocks.

An interesting feature of the level is the presence of a great block of Lorrain granite completely enclosed in the Nipissing diabase. It is evident that the granite block was caught up by the molten diabase sill during the time that the sill was being intruded through the older rocks. The main mass of the Lorrain granite occurs southeast of the Beaver mine; consequently it would appear that the molten diabase sill moved during its intrusion from the southeast towards the northwest. The inclusion of granite is at least 150 feet long and 65 feet wide. The stope, which follows a vein up into the granite mass, was not accessible, so that we were not able to find out how high above the level the granite extended. The granite does not, however, occur on the level above, namely, the 396-ft., nor does it occur on the level below, namely, the 530-ft. Where examined, it was noted that only a foot or two of the Nipissing diabase sill intervened between the top of the granite mass and the overlying Keewatin, so that it may be said that the granite inclusion practically floated at the top of the molten sill. Vein No. 2 cut through the granite inclusion, the Nipissing diabase, and the Keewatin rocks.

The chert formation has a maximum width of 155 feet. It is wedge-shaped in plan, gradually pinching out at a distance of 360 feet north of the south boundary of the Beaver. The bedding at the south end of the chert dips about 55° to the west. Near the shaft the chert is cut by a dike of lamprophyre which dips at very gentle angles.

The Beaver fault, which occurs at the northeast corner of the workings, has been drifted on for over 200 feet. It strikes northwestward, dips steeply to the northeast, and shows about eight inches of fault breccia and gouge. A vein occurs in the fault, and the management of the mine stated that some of the richest ore obtained was mined from the vein in the fault. This rich ore occurred where three productive veins ran into the fault, the veins entering at about right angles. The ore in the fault was obtained between the 456-ft. and the 396-ft. levels.

It is evident that the Beaver fault is older than the veins, since the productive vein referred to in the preceding paragraph occurs in the fault. But it would also appear that there has been a little movement along the fault after the veins were deposited, because one of the veins which crosses the fault at about right angles and extends beyond it, has been faulted about two feet.

The sinister influence of the Beaver fault in regard to ore shoots is well illustrated on this level. While some of the veins extend to the northeast of the fault no silver ore occurs to the northeast of it. For example, one of the main veins of the mine, the No. 5, extends to the northeast of the fault about 250 feet, but is not productive along that part. It would appear that the absence of silver ore in quantity on the properties which are immediately north of the Beaver is due to the presence of the Beaver fault. This fault may have acted as an impermeable barrier which prevented the silver solutions from circulating to the northeast.

The direction and extent of the displacement along the Beaver fault is not known.

396-ft. Level.—The workings are almost entirely in the Keewatin rocks, except at the northwest corner, where the Nipissing diabase has been met with in two drifts and a crosscut. The bed of chert has been encountered, showing dips of 51° to 63° to the west, and the workings are such that this bed has been proven to pinch out at a distance of about 350 feet north of the south boundary of the property. The Keewatin basalt along the west side of the chert bed is partly impregnated with iron pyrites.

The Beaver fault also occurs on this level and has been followed for about 200 feet. It strikes northeastward and dips at one place 61° to the northeast. A vein of calcite and quartz, four or five inches wide, occurs in the fault. There are some four inches of fault breccia and gouge in the fault.

The plan of this level shows a fine-grained lamprophyre dike, which was met with while following No. 5 vein. On the south wall of the dike there is a fault showing about a foot of fault breccia and gouge. The vein passed through this dike and fault.

347-ft. Level.—Compared with levels below, this level has very little work done. The No. 5 vein has been followed for over 600 feet; and there has been about 125 feet of drifting done on the other veins west of the No. 5. The level is all in Keewatin rocks, including the chert formation, the bedding of which dips westward about 65° .

297-ft. Level.—The workings on this level are almost as extensive as are the workings on the 396-ft. and 456-ft. levels. The rocks encountered are all Keewatin and consist of basalt and the chert bed.

The Beaver fault has been drifted on for 275 feet, and shows several inches of gouge and fault breccia. There is a calcite vein in the fault which pinches out entirely in places.

The rock immediately west of the chert formation is impregnated with iron pyrites, some of which occurs in roundish or cylindrical nodules.

235-ft. Level.—This level has about 800 feet of workings, all in Keewatin basalt.

199-ft. Level.—The workings are comparatively extensive, and are all in the Keewatin except at the northwest corner where the Nipissing diabase was met with in a crosscut. The Nipissing diabase is fine-grained at its contact with the Keewatin. The contact is about vertical, and there has been some movement along the contact, as is shown by the presence of two or three inches of fault breccia and gouge.

Some of the veins on the level consist largely of quartz with subordinate quantities of calcite.

The chert formation is narrow—about 35 feet in width.

77-ft. Level.—The level consists of an east and west crosscut about 600 feet long, which has intersected about a dozen non-productive veins, most of which are quartz. At the east end of the crosscut there is a quartz vein twelve to fifteen inches wide.

The chert bed on this level is about 50 feet wide; some of the chert is almost black.

SENECA-SUPERIOR

The Ontario Department of Mines is indebted to W. E. Segsworth for the following description of this property. As Mr. Segsworth was not only largely responsible for the discovery of the Worth vein, but was also managing director of the company during the period of its operation, he is in a position to write authoritatively regarding the property.

The Seneca-Superior Silver Mines, Limited, was incorporated in October, 1911, to acquire and operate three leases under Peterson Lake. These leases are shown on the plan (Fig. 36), and have an area of approximately ten acres each. One was situated under Peterson lake proper and was called the upper lease. The two contiguous leases under Cart lake were collectively referred to as the Cart lake lease, and had a combined area of about 21 acres. It was from this Cart lake lease that all the production came. The surface was covered with water except a 33-foot road allowance around the shore.

These leases were held on a royalty of 25 per cent. of the gross smelter returns to be paid to the Peterson Lake Mining Company. They were formerly operated by the Kerry Mining Company of Rochester, New York. This company did most of its exploration on the upper lease, and found small patches of high-grade ore, but no ore in commercial quantities. The upper lease was abandoned by the Seneca Company after a careful examination had been made, and subsequent exploration by the Peterson Lake Company did not disclose ore in commercial quantities.

The Seneca Company commenced operations in January, 1912, and confined its work to the Cart lake lease. The Kerry Company had previously trenched all the shore line, had done some diamond-drilling, and had sunk several test pits and two shafts. No. 2 was down 50 feet and No. 1, 110 feet. Three short drifts had been run at the 100-foot level in shaft No. 1. None of this work disclosed any ore on the Cart lake lease.

The plan showing the workings under Cart and Peterson lakes is in the pocket at the back of this report.

Before commencing operations, the Seneca Company's officials made a close study of the geology and ore deposits in the Cart lake area. The accompanying geological sections (Fig. 31), were made before operations commenced, the contacts in the Seneca No. 1 shaft and the position of the Worth vein being added subsequently. This study shows a flat dish-shaped bed of conglomerate of the Cobalt series resting on Keewatin greenstone. The bed was about 350 feet deep at its deepest part. The diabase sill, the remnants of which in this vicinity form Diabase mountain, at one time lay over the conglomerate with its lower surface perhaps 100 to 200 feet above the lake level, or 450 to 550 feet above the Keewatin contact. A bed of slate-like greywacké, locally called slate, occurred at 70 feet above the Keewatin contact. This bed dips at more gentle angles than the dip of the Keewatin floor, and it rests on, or is near, the Keewatin

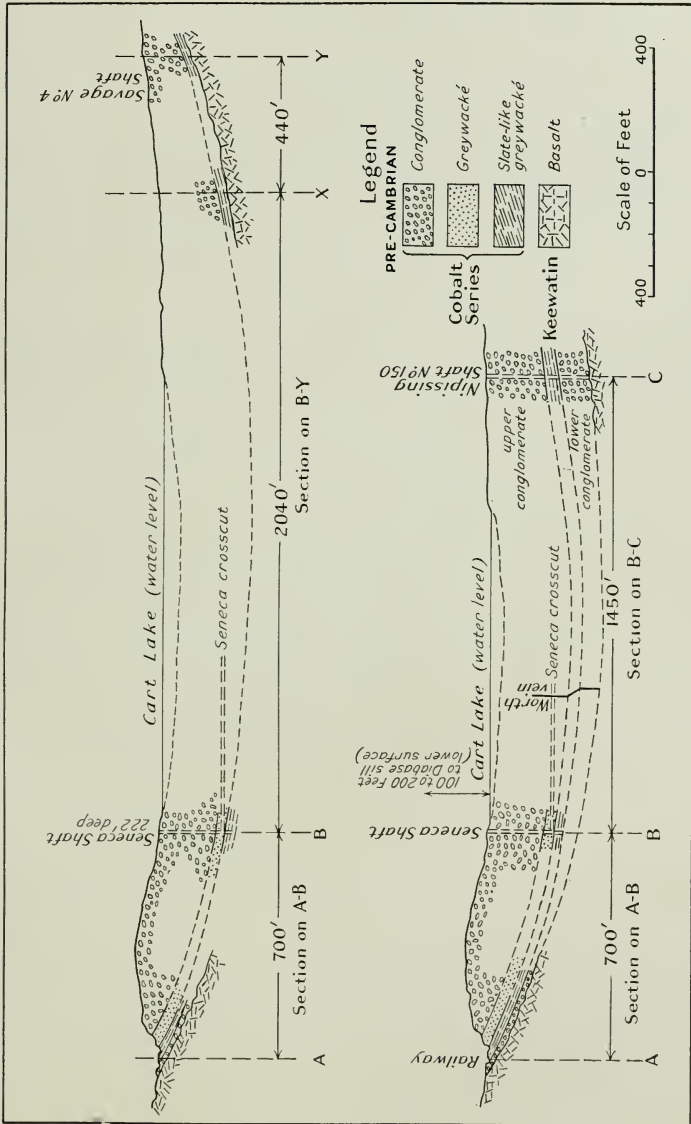


Fig. 31—Vertical sections through the Seneca mine, prepared by W. E. Segsworth.

contact around the rim of the basin. The bed was identified in the Little Silver shaft of the Nipissing, the Nipissing shaft No. 150, and in the Savage and Provincial mines. In these properties several instances were found where veins contained high-grade ore above, and in, this slate bed, and the same veins underneath the slate were rich in cobalt but contained little if any silver. The theory was therefore adopted, and afterwards proved true, that in this particular basin the locus of the richest ore was just above the slate bed. Many of the ore-bearing veins on the surrounding properties, namely, the Nipissing, Savage, and Provincial mines, had a northeast strike. It was therefore decided to sink the No. 1 shaft to the slate bed, and drive a crosscut perpendicular to the strike of the veins just above the slate.

Operations were commenced, following out this plan, in January, 1912. The slate was reached at 200 feet, a sump cut, a level established, and a crosscut, in a southeasterly direction, started at 200 feet. On October 10th, 1912, this crosscut had reached a distance of 439 feet from the shaft, and at that point encountered a small stringer of ore which, in the next round, broke into the Worth vein.

The development of this vein disclosed an oval-shaped vertical lens, or ore-shoot, of high-grade ore with a northeast strike. This lens had a maximum horizontal length of 440 feet on the Seneca, and extended about 50 to 60 feet into the adjoining Gould Consolidated (Mercer), giving it a total length of 500 feet. The lens rested on the Keewatin contact and had a maximum height of 250 feet above the contact. The upper limit of the lens would be about 200 to 300 feet below the bottom of the diabase sill.

The average assays on the stope maps prove that the ore was richest in the upper levels. The Cobalt content was greatest in the lower levels. The first level just skimmed the top of the ore-shoot. The ore in the top of the vein was calcite, free from cobalt, rich in native silver, and about four inches wide. The ore near the contact was a dense hard smaltite ore, practically free from visible native silver or calcite. The pillars on the stope map represent barren areas in the vein. These barren areas were larger than shown by the pillars.

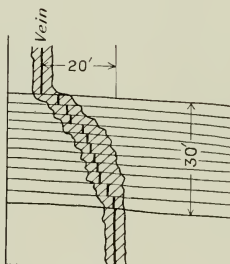


Fig. 32—Illustrating what happened to "Worth" vein, Seneca mine, when vein passed through a 30-ft. bed of slate-like greywacké. Drawing furnished by W. E. Segsworth.

The slate bed between the second and third levels furnishes the most interesting feature of this ore deposit. At the southwest boundary, it is 30 feet thick, and thins out to a point 230 feet to the northeast. This slate profoundly affected the deposition of the ore. Above the slate and in its upper part, the ore assayed 3,500 ounces of silver per ton, but immediately below, the silver content dropped to 2,000 ounces per ton, and from there decreased in value to 900 ounces near the Keewatin contact. This phenomenon was beautifully illustrated on the third level where, in drifting to the northeast, the assays jumped from 2,000 ounces to 3,800 ounces per ton immediately the drift passed from under the slate bed.

The slate bed has a strong parting along the bedding plane and, as shown in the transverse section of the vein, "step-faulting" occurred in the slate, the total throw being 20 feet (Fig. 32). The slipping of the layers over each other left the structure quite open, and converted the slate bed into a favourable water course. The wall-rock in the conglomerate was dense and hard and, compared with the slate, did not offer favourable conditions for the circulation of solutions. It is probable that the silver solution in its descent from the diabase sill was diluted or escaped in the slate. On the other hand, the increase in cobalt under the slate might indicate that the cobalt was deposited before the silver and before the faulting in the slate had opened it to the circulation of solution.

Apart from this step-faulting in the slate, no faults of any importance were found.

The Seneca vein was rather unique in that no mill-rock was found in the conglomerate walls. What small amount of ore was milled was the undersize from the sorting tables, too small to be handpicked, the large pieces with vein matter attached which could not be cobbled, and a little disseminated ore from the Keewatin.

A winze was sunk 75 feet below the fourth level (Fig. 33), and the vein was found to feather out into numerous small stringers and disseminated ore and then to disappear in the Keewatin. The average assay of 1,872 tons milled from this rock below the fourth level was 16.5 ounces per ton.

When the Seneca company abandoned operations, it left a small amount of this ore in place as it could not be profitably extracted and milled owing to the 25 per cent. royalty payable to the parent company.

The rocks below the fourth level, which were tapped by the winze above referred to, form an interesting study. As shown by the vertical section (Fig. 33), the winze encountered a bed of slate, immediately below the level, having a thickness of 15 feet, 6 inches. Below the slate, a bed of conglomerate was found. This conglomerate is composed almost wholly of fragments and boulders of the underlying Keewatin, although there are a few granite pebbles and boulders. Northeast of the winze the slate bed gradually rises and becomes thinner, and when it reaches the fourth level it is only six feet thick, and is found resting directly on the Keewatin. Thus there is at the bottom of Cart lake a basin or trough in the Keewatin. This basin was first

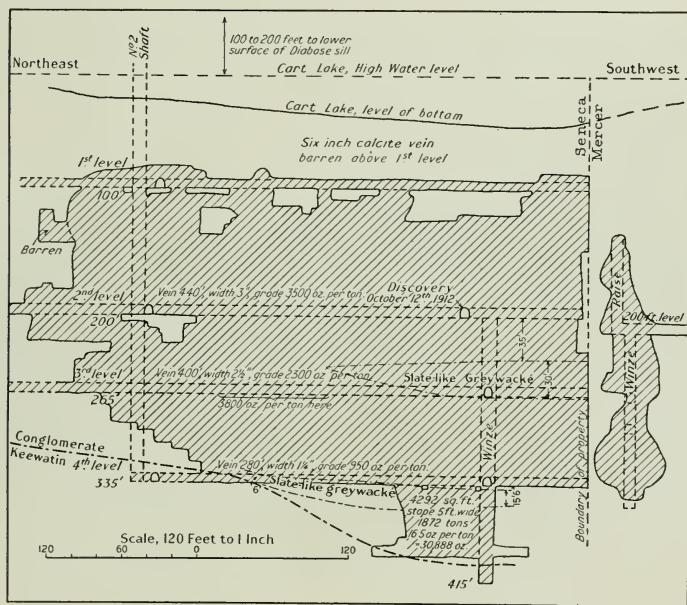


Fig. 33—Stope section of Worth vein, Seneca mine, prepared by W. E. Segsworth.

filled with conglomerate of the Cobalt series, the conglomerate consisting almost wholly of Keewatin fragments and boulders together with a few granite pebbles and boulders. Conditions of deposition then changed and a bed of slate-like greywacké, locally called slate, was laid down. Above the central parts of the basin, the slate rested on the conglomerate, but higher up on the sides of the basin the slate was deposited directly on the Keewatin (Fig. 33). There is thus very good evidence to show that this basin was not caused by folding, but was formed in the usual way by erosion before the Cobalt series was laid down.

The Worth vein was the only ore-bearing vein found on the Seneca property. In all, 7,665 feet of exploration work was done in an effort to find other productive veins, but without result. The plan of the mine shows this exploration, which covered practically the whole of the property. The Seneca presents one of the few instances in the Cobalt area of a paying mine being established on a single isolated ore-shoot.

All profitable ore was extracted early in 1916, and the mine was closed, the plant sold, and the lease abandoned that year. In a period of less than four years the mine produced 5,639,093 ounces of silver from the one ore-shoot.

The following figures from the annual report of the company at the end of the year 1916 are interesting:—

Production 5,639,093 ounces at 55.3 cents per oz. \$3,118,938.54

Less:

Royalty.....	\$751,381.87	
Smelter deductions.....	68,164.81	
Freight and treatment.....	108,112.21	
		<u>927,658.89</u>

Gross receipts from shipments..... \$2,191,280.65

Less:

Mining and operating.....	\$576,606.05	
Head office charges.....	78,510.86	
War tax.....	15,245.39	
		<u>670,362.30</u>

Net profits on operations.....\$1,520,918.35

The costs over the whole operation were:		Cents per oz.
Royalty.....	\$751,381.87	13.33
Smelter deductions.....	68,164.81	1.22
Freight and treatment.....	108,112.21	1.93
Mining and operating.....	576,606.05	10.22
Administration.....	78,510.86	1.40
War tax.....	15,245.39	.28
Total cost.....	\$1,598,021.19	28.38
Profit on operation.....	1,520,918.35	26.92
Gross value.....	\$3,118,939.54	55.3

From the operating profit of \$1,520,918.35, as above, plus the money realized from the sale of the capital stock, the company paid \$1,582,211.62 in dividends, or \$3.30½ per share on its issued capital of 478,884 shares. The capital stock was sold for seventeen and a half cents per share.

The officers of the company were: S. Harry Worth, director and president; F. W. Zoller, director and vice-president; R. F. Segsworth, director and secretary-treasurer; W. E. Segsworth, managing director; Alvin H. Dewey, director; R. H. Lyman, mine manager, and T. D. Maguire, mine captain.

PENN-CANADIAN

Prior to its acquisition by the Penn-Canadian Mines, Limited, which was incorporated on April 24th, 1912, the property was worked by two other companies known as the Big Pete Canadian Mines and the Cobalt Central.

The total output of silver under all companies amounted to 3,752,610 ounces of silver.

When the property was examined during the latter part of the year 1920 it was not in operation, but most of the mine was accessible, and we were able to map all of the levels except the sixth. The information regarding this was kindly furnished by Balmer Neilly, manager of the Penn-Canadian company when the mine was last in operation.

The structure of the rocks at the Penn-Canadian and Bailey is shown in the vertical section facing page 40. The Nipissing diabase sill was met with down to the third level where it rests on a gently dipping bed of slate-like greywacké of the Cobalt series about 40 feet thick. Below the greywacké is conglomerate of the Cobalt series from a few feet to about 35 or 40 feet in thickness. The average thickness of the conglomerate and slate-like greywacké combined is about 70 feet. Below the Cobalt series is the Keewatin, which was not

productive. The Cobalt series is resting at an unusually flat angle, the dip being about 6° or 7° to the northeastward. The Nipissing diabase sill has for the most part forced its way along a single bed of the slate-like greywacké.

The Ontario Department of Mines is indebted to Mr. Neilly for the following description of the property.

The ore bodies so far developed were found on that portion of the property lying west of Glen lake or under Diabase mountain. As the latter name suggests, the diabase outcrops on the surface and the original discoveries were made in that formation; these same ore bodies produced some much decomposed rich ore down to a horizontal fault which was 20 or 30 feet above the bottom of the diabase sill.

The displacement of this fault was about 90 feet to the northwest. For 20 feet above the fault there was little ore, and the 20 or 30 feet of diabase below the fault was practically barren, although the veins were quite persistent.



Fig. 34—Penn-Canadian and Bailey mines; Glen lake in foreground.

Below the diabase is the slate-like greywacké of the Cobalt series, having an average depth of about 40 feet. Below the slate-like greywacké is the conglomerate of the Cobalt series varying in thickness from a few feet to 35 or 40 feet.

The downward extension of the "Big Pete", or discovery vein, was mined in the Cobalt series and found to occupy a long syncline with its axis a little east of north. Another main vein-system was developed in a syncline running at about right angles to the "Big Pete" vein.

From these two systems practically all the production to date was obtained.

To the northwest of the present workings there is evidence of another syncline, and, when work was discontinued at the time of the strike in 1919, a crosscut was being driven in the conglomerate of the Cobalt series in that direction.

The property situated east of Glen lake is practically undeveloped, except for a shaft sunk to a depth of 120 feet in the diabase. On the northern half of this lot the diabase rests on the Keewatin, but, toward the south and adjoining the Foster mine, such work as has been done indicated a considerable depth of the Cobalt series. This area of approximately 20 acres can be looked upon as almost virgin ground and undoubtedly will be further developed some time in the future.

DRUMMOND (COBALT COMET)

To the end of the year 1922, the production from this property amounted to 3,707,137 ounces of silver.

The property was bought by the Cobalt Comet Mines, Limited, the latter company having been incorporated on April 16th, 1913, with a capital of \$1,000,000.

The mine has not been in operation during recent years, and the Ontario Department of Mines is indebted to R. W. Brigstocke for the following account of the discovery of the mine, and description of the rocks and veins. Mr. Brigstocke was manager of the property until it was taken over by the Cobalt Comet Mines, Limited, in 1913.

Mr. Brigstocke discloses the important fact that the Cobalt series is only about 50 feet thick. And, as the Cobalt series is the only productive horizon, it is seen that the ore zone is a very shallow one indeed.

In the autumn of 1904, one year after the discovery of ore at Cobalt, the Drummond Mines was staked by M. P. Wright for Messrs. Drummond and associates of Montreal, amongst whom was Dr. W. H. Drummond, the well-known Canadian poet.

Mr. Wright found a calcite vein at the northerly end of the Kerr Lake property. This was the birth of that important section of the Cobalt camp known as the Kerr Lake section.

The geology of this section has been fully described in the government reports. As far as the Drummond Mine is concerned the southerly claim consisted of a small portion of Nipissing diabase, a small portion of conglomerate of the Cobalt series, and the remainder of Keewatin. The northerly claim consisted almost entirely of Nipissing diabase.

The conglomerate was the only rock in which ore was found, and it was not much more than 50 feet thick.

During the winter of 1904-5 a small shaft was sunk on the vein which Mr. Wright had discovered, but the result was disappointing. Work accomplished afterwards revealed no ore of importance. This was a strong calcite vein containing smaltite and niccolite and low silver values.

In the spring of 1905 further prospecting exposed the veins that constituted the birth of the Drummond Mines as a producer. There were two veins 6 feet apart, and a small one in the centre consisting of calcite, smaltite, and silver, but very little niccolite. Some portions yielded up to 14 inches in solid smaltite containing only 200 ounces of silver and over 50 per cent. arsenic by the carload. This was exceptional, the general tenor being high-grade ore assaying up to 6,300 ounces of silver per ton by the carload.

Other veins were also found extending under the lake which produced high-grade ore.

The walls of all the producing veins yielded mill-rock. In places sheets of silver extended into the walls many inches.

The large producing veins of early discovery extended over 400 feet in length, which somewhat compensated for the shallowness of the conglomerate which, as already stated, is not much more than 50 feet thick.

On these veins a shaft was sunk to a depth of 200 feet, and levels opened up at 50, 100, and 200 feet.

No ore was found below the conglomerate which was, in the shaft, 50 feet deep. A small calcite vein extended downwards into the Keewatin, but no ore was found.

About the time that these early discovered veins were nearing exhaustion of high-grade ore, the whole property had been thoroughly trenched to bed rock and apparently nothing of importance was forthcoming.

A second lease of life was, however, in store. The ground between the original workings and the south boundary was considered worthy of intensive exploration. Believing that the conglomerate existed underneath some heavy overburden and below the diabase sill, a shaft was sunk on a small barren vein in the diabase. The conglomerate was found at a depth of about 75 feet, a level driven, and the shaft continued to a depth of 125 feet, where another level was driven. A patch of ore was found on each level, having no connection with one another.

In the meantime the old trenches were being cleaned out and the ground cut up into 50-foot squares. A vein was found about 20 feet long and feathering to nothing at each end; it was about 2 inches wide in the centre and contained 2,000 ounces of silver to the ton.

The 75-foot level of these new workings was extended about 60 feet to cut the vein, which was found to be about 3 inches wide of high-grade ore. The same thing occurred on the 125-foot level.

This vein was followed and other veins disclosed, resulting in the discovery of several high-grade veins which yielded their share of high-grade ore and mill-rock.

In 1913 the mine was sold to the Cobalt Comet Mines, Limited, which carried on successfully to the end.

RIGHT OF WAY

The Right of Way Mines, Limited, has a capital of \$2,000,000 of which \$1,685,500 has been issued. The shares have a par value of \$1.00. The company has produced 2,961,353 ounces of silver and has paid \$252,825 in dividends to the end of the year 1922.

The company worked the "right of way" of the Temiskaming and Northern Ontario railway at the north end of Cobalt lake, and at the south end. At the north end the extension of the main La Rose vein was mined, while at the south end veins from the Silver Queen and Townsite were operated. The property was not being worked in the year 1921.

The workings north of Cobalt lake will first be described; the plans of this part are shown on sheet No. 31a-14.

Workings North of Cobalt Lake

Most of the two important levels, the 83-ft. and the 143-ft., were dammed off by concrete dams, making them inaccessible. The writer regrets that he was not able to examine this part of the mine; it is reported that the junction of the main La Rose vein and the Cobalt lake fault was met with during mining operations in these levels. It is unfortunate that there are no published records, in so far as the writer is aware, concerning the structural relation of the main La Rose vein to the Cobalt lake fault. The writer, however, obtained the following information from D. Angus, who was at one time in charge of the Right of Way. Mr. Angus states that La Rose vein entered the Right of Way property and continued southwestward, finally running into the Cobalt lake fault; that it followed the fault for 25 or 50 feet, and that it then turned south and gradually left the fault. The part of the vein in the fault and north-east of it was productive, but the part to the south of the fault was not productive and appeared to pinch out. It may be added that La Rose vein together with its southwestward extension into the Right of Way was on the southeast side of the Cobalt lake fault. The vein has never been found on the northwest side of the fault.

Judging from the verbal descriptions which the writer has obtained regarding the structural relation between the main La Rose vein and the Cobalt lake fault, it is evident that the vein is younger than the fault.

The Right of Way shaft, No. 2, is about 280 feet northeast of the north end of Cobalt lake. There are four levels from this shaft, at 83, 143, 358, and 410 feet below the collar of the shaft. The lowest level, the 410-ft., is reached by a winze from the 358-ft. level. The winze was said by the management to extend some distance below the 410-ft. level; it was flooded at the time of our examination, but as the rock below the 410-ft. level is Keewatin it would not appear to have much economic significance.

410-ft. Level.—The level consists of a drift about 70 feet long in the Cobalt lake fault. No cobalt bloom was noted in the fault, although there are irregular stringers of calcite in it.

The bottom of the Cobalt series occurs at the winze, so that these rocks have a thickness of about 410 feet on the north side of the Cobalt lake fault.

The Chambers-Ferland made use of this level to operate their property to the north of the Right of Way. With the exception of the drift on the Cobalt lake fault, the entire level is on the Chambers-Ferland property. The level is described in that part of the report dealing with the Chambers-Ferland.

358-ft. Level.—This level was also used by the Chambers-Ferland to work their property to the north of the Right of Way. The level is described on page 165.

143-ft. Level.—Practically all of the level was dammed off by a concrete dam, so that only the crosscut for 100 feet northeast of the shaft could be examined. This part of the level is on the south side of the Cobalt lake fault. The contact between the Keewatin and Cobalt series occurs about 10 feet north of the shaft, and strikes northeastward. In the shaft the contact occurs about 4 feet above the floor of the crosscut. About 60 feet northeast of the shaft, there is a bed of slate-like greywacké one foot thick. The dip of the Cobalt series may be readily ascertained from this bed, and it is seen to be dipping about 20° to the northwestward. There is a crushed zone along this bed of slate-like greywacké, indicating some slight movement, how much was not ascertained. Above the bed of slate-like greywacké is quartzite.

83-ft. Level.—The north part of the level was dammed off by a concrete dam; the south part was accessible. The latter consists entirely of the Cobalt series except a short crosscut at the east side, in the Chambers-Ferland ground, which consists of Keewatin. The Cobalt series dips at about 10° to the northwest.

About 10 feet north of the shaft, there is a minor fault dipping 20° to the northwestward. There are no veins except a small barren calcite one at the south end of the workings. From this level the Chambers-Ferland did some work on its property to the north.

Mine Workings South of Cobalt Lake

The Right of Way mine at the south end of Cobalt lake was worked from two shafts, Nos. 3 and 4. There are two levels, the upper one of which is known as the 75-ft. level. This level consists of a crosscut more than 1,700 feet long, running parallel with the railway track. At the time of examination, early in August, 1921, the level was partly flooded, and we were only able to examine the north half of the workings for a distance of about 800 feet. The crosscut in this north part of the workings encountered five veins, four of which have been more or less stoped. The veins strike northwestward. The one which is 340 feet north of No. 3 shaft has been stoped for a width of 10 to 20 feet. There was water in this stope 30 or 40 feet below the level, at the time of examination. On this level a fault may be seen intersecting this vein. The fault strikes northward, and dips at an angle of 37° to the east. Its relation to the vein could not be worked out.

The stopes on the other three small veins are narrow, 5 or 6 feet in width. At the north end of the property there is a vertical fault, which has a fault breccia and gouge 1 to 12 inches wide. A small vein of calcite with cobalt bloom parallels the fault.

The north end of the crosscut follows a fine-grained greywacké and slate-like greywacké for about 550 feet; to the south of the slate is conglomerate as far as we could explore. Keewatin is reported at the south end of the crosscut. The upper part of No. 4 shaft is conglomerate, below which is the bed of greywacké and slate-like greywacké to the 75-ft. level, and for a few feet below.

The first level of the Right of Way is about the same elevation as the second level of the Silver Queen.

The second level of the Right of Way was not accessible.

SILVER QUEEN

The Cobalt Silver Queen, Limited, has a capital of \$1,500,000, all of which has been issued. The par value of each share is \$1. The company has produced 1,225,111 ounces of silver, and has paid \$315,000 in dividends to the end of the year 1922.

At the time of examination in August, 1921, the property was idle, although the rock dump was being shipped.

The workings in this mine are not extensive, as the plans of the levels show. The Cobalt series is shallow, and there are only two veins of importance on the claim. There are three levels, the two lower of which were flooded and inaccessible in the year 1921.

The property was worked from an inclined shaft, which dips southward at an angle of about 60°. The main vein strikes a few degrees north of west. In the conglomerate and greywacké of the Cobalt series this vein is about vertical, but, on entering the Keewatin, it flattens out and dips at an angle of about 60° to the south. At the station on the first level, the vein may still be seen in the Keewatin; it is in places 5 or 6 inches wide consisting mostly of calcite. A drift follows this vein westward from the shaft along the first level for 600 feet; unfortunately at the time of examination this drift was blocked, but it was reported that the drift was all in Keewatin and that the calcite vein persists throughout and contains in places 3 or 4 inches of smaltite.

A fault, corresponding in position to the "contact" fault, occurs on the first level, but it is poorly defined and shows, as a general rule, only an inch or two of fault breccia and gouge.

The other vein on the property occurs at the northeast corner of the claims; it extends into the Townsite, and thence into the Right of Way mine.

The second level was inaccessible, but it was reported that the contact between the Keewatin and the Cobalt series is about 270 feet east of the shaft. The second level of the Silver Queen corresponds to the first level of the Right of Way.

In 1921 the Cobalt Silver Queen was under lease to Mr. W. J. Post, to whom the writer wishes to express thanks for courtesies extended during the examination.

CHAMBERS-FERLAND (ALADDIN)

The Chambers-Ferland mine was operated by the Aladdin Cobalt Company, Limited, which was incorporated on August 23rd, 1912, with a capital of \$500,000 in shares of a par value of \$5 each. The company has paid in dividends \$75,000. The Aladdin Company has been liquidated, and superseded by the Kirkland Lake Proprietary (1919), Limited, which is also the holding company of the Tough-Oakes Gold Mines, Limited, and the Burnside Gold Mines, Limited.¹

The old Chambers-Ferland produced 1,107,810 ounces, and the Aladdin produced 1,067,658 ounces of silver.

The main workings of the Chambers-Ferland were operated from No. 4 shaft. The veins in this part of the mine are mostly the eastward extensions of veins Nos. 98 and 490 of the Nipissing, and these veins produced most of the ore for the Chambers-Ferland.

At the southwest corner of the property certain veins were worked, using the No. 2 shaft of the Right of Way. These workings are not connected with the No. 4 shaft workings.

¹Annual Report, Ont. Dept. Mines, Vol. XXX, pt. I, p. 107.

Some work has also been done on the Chambers-Ferland, which lies north of the northwest corner of the O'Brien mine.

The No. 2 shaft on that part of the Chambers-Ferland south of La Rose was not examined.

Workings from No. 4 Shaft

The most productive vein at this end of the property, in fact on the entire property, is reported to be vein No. 15. This vein is said to be the eastward extension of vein No. 98 on the Nipissing. Vein No. 98 is the most important branch of the Meyer vein of the Nipissing. Vein No. 15 was followed for about 200 feet eastward from the Nipissing boundary, but it was only stoped for about 80 feet east of the boundary.

The next important vein on the property is No. 14. This vein is the eastward extension of vein-system No. 490 on the Nipissing—a very important system on the Nipissing property. It is reported to have produced some 100,000 ounces of silver on the Chambers-Ferland. These two veins, Nos. 15 and 14, are the tale-end, so to speak, of two very productive veins on the Nipissing.

On this part of the Chambers-Ferland mine there are six levels, namely, 525-ft., 480-ft., 453-ft., 425-ft., 350-ft., and 275-ft. These levels may now be described, beginning with the lowest. Unfortunately most of the levels were inaccessible, due to concrete dams at the north ends of the workings. During the time of our examination, we gained access to the mine from the fourth and sixth levels of the Nipissing mine.

525-ft. Level.—The level is reached from a winze on the 425-ft. level. It was flooded at the time of our examination. The fault known as No. 64 on the Nipissing was reported to have been met with near the south end of the level, and it was drifted on for about 40 feet.

480-ft. Level.—This is a small level with about 250 feet of workings operated from winze D. It is about 30 feet above the sixth level of the Nipissing. In our examination we entered the level by way of a raise at the north part of the sixth level of the Nipissing.

There are a number of short veins on the 480-ft. level. No. 6 at the north end has been followed 50 feet northeast of the Nipissing boundary line. Near the northeast end, it meets a prominent fault. The vein goes through the fault and has been followed to the northeast of the fault for about 10 feet, although on the northeast side of the fault the vein is a mere crack showing nickel and cobalt bloom.

Vein No. 4 may still be seen in the back of the drift and shows 1 to 2 inches of smaltite and calcite. Vein No. 3 has less than half an inch of smaltite. Veins Nos. 1 and 2 join just before encountering the fault.

The fault referred to in preceding paragraphs, and shown on the plan of this level, may be the northward extension of what has been called the "valley" fault on the Nipissing. It has a fault breccia of 12 or 15 inches in places, and a gouge fractions of an inch wide. It strikes a few degrees east of north and dips at an angle of 76° to the eastward. The fault is a reverse one with a displacement of about 33 feet. On the Nipissing, however, at winze No. 73-4014, a distance of 350 feet south of the Chambers-Ferland 480-ft. level, the "valley" fault has a displacement of some 75 feet. It would appear therefore that the displacement along the valley fault becomes greater to the south.

Only one of the veins on the 480-ft. level was observed to pass through the fault; this was No. 6 vein, which, as already stated, was followed for 10 feet northeast of the fault. The vein was not faulted. Elsewhere on the Chambers-

Ferland and Nipissing, the veins pass through this fault without any displacement so far as the writer has observed. This would appear to show that the veins are younger than the faults.

453-ft. Level.—This is a small level, only about 27 feet above the 480-ft. level. On account of caving, we were able to examine only a few feet in the vicinity of winze D. It was observed that the contact between the Keewatin and Cobalt series is 6 feet above the floor of the level.

425-ft. Level.—This is the most extensive level in the Chambers-Ferland mine. A concrete dam near vein No. 15 prevented an examination of the north part of the level. In this inaccessible part it was reported that fault No. 64 was met with and drifted on for 450 feet. No ore was reported in the fault, although a little calcite occurs here and there.

In the accessible portion of the workings the most northerly vein is No. 15, which is the eastward extension of vein No. 98 on the Nipissing, the most important branch of the great Meyer vein. Vein No. 15 has been stoped for about 80 feet east of the Nipissing boundary and has been drifted on for 120 feet farther east. Just east of the stope the vein splits into two branches, the south branch of which has 1 to 5 inches of smaltite and calcite, but contains little or no silver. Towards the east these two branches gradually pinch out until, on the east faces of the two drifts, the veins are mere cracks, an eighth of an inch or less, containing gouge-like material. Thus dies out the eastward extension of one of the greatest veins in the Cobalt area.

Vein No. 18 has been stoped for nearly 100 feet east of the fault shown on the plan. This fault is described below.

Vein No. 14, said to be the Nipissing vein No. 490, has also been stoped for nearly 100 feet east of this fault.

The fault referred to above has been drifted on for about 300 feet. It dips steeply eastward, in one place at an angle of 68° . All of the veins which we examined pass eastward through this fault. Vein No. 15 was stoped for a distance of 30 feet east of the fault, and veins Nos. 14 and 18 were, as previously stated, stoped about 100 feet east of it. We were not able to observe the relation between the fault and the veins; it is reported, however, that the veins were not faulted.

This fault may be the northward extension of the "valley" fault on the Nipissing; this we were not able to prove.

All the accessible part of the 425-ft. level consists of the Cobalt series.

350-ft. Level.—The north part of the level was not accessible. It was reported that fault No. 64 was met with and followed for over 400 feet. No silver was found in the fault, but a little nickel bloom occurred at the west end.

There are four calcite veins on the level, none of which were productive.

The long crosscut extending southwestward from No. 64 fault is entirely in finely bedded, slate-like greywacké of the Cobalt series. The greywacké dips southeastward at an angle of about 7° to 9° .

Winze D and crosscut extending east therefrom reveal an interesting structure in the Cobalt series. In the winze the bedding dips gently to the west, while, about 60 feet east of the winze, the bedding begins to dip southeastward at angles of 7° to 8° and continues this southeastward dip to the east end of the crosscut. Thus there is here an anticline in the sediments of the Cobalt series; or, if not an anticline, then the sediments follow the contour of a gentle hilltop in the underlying Keewatin. It is not known how far east this southeastward dip continues, but it is likely that, as the Cobalt lake fault is approached, the sediments will be found turned up and dipping again westward.

The part of the level which was examined is entirely in the Cobalt series.

275-ft. Level.—Vein No. 15 was met with at the north end of the level where it has been stoped for about 65 feet east of the Nipissing boundary. It is reported that high-grade ore was obtained. East of the stope about 40 feet, the vein splits. The north branch was followed for about 55 feet and found to pinch out to a mere crack; but the south branch was a strong vein, showing up to 4 inches of smaltite and calcite; it was followed for 120 feet. The east face of the drift still showed an inch of smaltite.

In winze D, there is a bed of slate-like greywacké about 49 feet thick; it was met with 14 feet below the 275-ft. level, and 12 feet above the 350-ft. The bedding of the greywacké dips gently westward.

Workings from No. 2 Shaft, Right of Way

The Chambers-Ferland mine obtained permission from the Right of Way mine to use the latter's No. 2 shaft. This shaft is conveniently located so that the Chambers-Ferland could operate its property immediately to the north of the Right of Way No. 2 shaft. There is no connection between these workings and those from No. 4 shaft.

Several small veins were worked in this part of the Chambers-Ferland mine; these veins strike nearly at right angles to the Cobalt lake fault.

There are three levels, the 410-ft., the 358-ft., and the 83-ft. Commencing with the lowest, these levels are described below.

410-ft. Level.—The level is reached by a winze from the 358-ft. level of the Right of Way. There are about a dozen small veins consisting mostly of pink calcite and a little smaltite. These veins all average less than an inch in width, although they are larger in places. Only one, No. 21, at the south end has been productive, and it was stated that it produced about 30,000 ounces of silver. The stope on this vein extends into the Nipissing, which also obtained some ore from the vein. The stope is below the 410-ft. level. Where the vein is still exposed in the back of the drift, it is seen to be a pink calcite vein up to 2 or 3 inches wide, but averaging much less.

Vein No. 23 shows about three-quarters of an inch of smaltite on the west face of the drift.

Vein No. 28 is at the north end of the level. It is only about a quarter of an inch wide at the west end, but at the east end is as wide as an inch and a half. At the east end, the wall rock is impregnated with native silver. The vein consists mostly of pink calcite with a little smaltite.

The Cobalt lake fault is at the south end of the workings, but is on the Right of Way property about 30 feet south of the boundary. The Keewatin is on the south side of the fault, and the Cobalt series on the north. The fault has been drifted on for 70 feet, and dips about 60° to the southward. The strike of the fault is a little unusual here, being a few degrees north of east. No cobalt bloom was noted in the fault, and only a few irregular stringers of calcite a few inches long here and there were observed.

The contact between the Keewatin and conglomerate north of the Cobalt lake fault occurs at the winze on the Right of Way property and, as far as could be determined, strikes a few degrees east of north. The dip of the bedding of the Cobalt series is about 10° to the west. There are two winzes at the north part of the workings, in the most northerly of which Keewatin was said to be encountered about 7 feet below the level, while in the other winze the Keewatin was said to be encountered about 10 feet below the level.

358-ft. Level.—There are only three small pink calcite veins on this level, none of which were productive.

At the north end of the level, what was considered to be the southeastward extension of vein No. 490 on the Nipissing was encountered. The location of this vein, which is small, is not shown on our plan of the 358-ft. level.

South of this vein, a vein known as No. 28 was explored in a raise to a height of about 81 feet above the 358-ft. level. The vein in this raise was small, and at the top was a mere crack. The first 14 feet of rock in the raise was said to be slate-like greywacké, finely bedded and similar to that on the level. On top of the slate it was stated there was a bed of quartzite 60 feet thick, above which is conglomerate to the top of the raise. A few feet of drifting was done on the vein at the top of the raise with no results. Most of this level is in a finely bedded, slate-like greywacké which dips at very gentle angles. At the south part it dips at about 10° northwestward, while at the north end it dips about 5° southward, forming a gentle basin. Ripple marks are common in this rock.

The Cobalt lake fault was encountered 100 feet north of the shaft and was followed by a drift for 200 feet; but all the work on the fault was done in the Right of Way property. The fault contains only a few short stringers of calcite.

At the point where the drift leaves the Cobalt lake fault, there are two or three fractures parallel to the lake fault and within some 10 feet of it. These fractures contain cobalt and nickel bloom.

83-ft. Level.—In the crosscut north of the Right of Way No. 2 shaft, the Cobalt lake fault was intersected. Just south of the fault there is a vein up to 2 inches in width, consisting of calcite and a little smaltite. No. 3 shaft of the Chambers-Ferland was sunk on this vein, but it was apparently of no economic importance.

Southeast of No. 2 shaft, there is a crosscut running into that part of the Chambers-Ferland which is south of La Rose. The Keewatin was encountered in this crosscut; resting directly on top of the Keewatin is a bed of slate-like greywacké of the Cobalt series with little or no conglomerate intervening.

Workings North of the Northeast Corner of O'Brien

These workings were practically inaccessible at the time of examination, but the plans are published on sheet No. 31a-14. Fault No. 64 had some work done on it, and a little high-grade ore was reported to have been found. The fault may be seen on the adjacent La Rose property in the face of the cliff, and in the tunnel on vein No. 10.

FOSTER

The Foster property, at the time of our examination in the autumn of 1920, was under lease to the Mining Corporation of Canada, Limited, and was being operated under the name of the Central Operating Company, Limited. The total output of silver from the property amounted to 815,346 ounces. The old company, the Foster Cobalt Mining Company, Limited, was capitalized at \$1,000,000, of which \$915,588 were issued. The par value of the shares was \$1. The old company paid \$45,000 in dividends.

Prior to the operations of the Mining Corporation, the property was under lease to Mr. C. L. Campbell who found a small though very rich ore-shoot in No. 6 vein.

The only known veins occur at the southeast end of the property. The vein-system is an unusually regular one, consisting of a number of parallel veins

striking northwest, and a number of parallel veins striking northeast. An interesting feature of the veins which strike northwest is that two of them follow narrow bands of cherty rocks which may possibly belong to the Keewatin "iron formation." It is evident that the fractures in which these veins occur followed the line of weakness formed by the "iron formation." In the Cobalt camp other examples occur in which veins follow the strike of the Keewatin "iron formation", notably in the Buffalo and Hudson Bay mines.

The Cobalt series on the Foster is quite shallow at the south end where the veins occur. There is just a narrow fringe of this series along the southeast shore of Glen lake. Consequently, practically all of the mine workings are in the Keewatin series.



Fig. 35—Foster and Lawson mines; Glen lake in foreground, Giroux lake in background.

The rich ore-shoot found by Mr. C. L. Campbell occurred in the Keewatin, and was in vein No. 6 between the 40-ft. level (elevation 981.6 feet) and the 70-ft. level, in the vicinity of No. 6 shaft.

On the 40-ft. level, there is a fault dipping steeply northeastward. The writer was informed that in vein No. 23 no silver was found northeast of this fault, except a little on the surface. The fault, as in many other instances in Cobalt, appears to have had some influence in the deposition of the silver.

On the 210-ft. level, there is an exploratory crosscut and drift running almost entirely across the property in a northwestward direction. A vertical section along the north part of this crosscut is printed on the sheet showing the plans of the Foster mine. The north part of the crosscut follows about the bottom of the Nipissing diabase sill. In working out the contacts on this level we found a large block of slate-like greywacké imbedded in the diabase at the winze. The block has a length of over 125 feet. The occurrence of large inclusions in

the Nipissing diabase is, curiously enough, quite uncommon in the Cobalt area. The two other conspicuous instances are at the Beaver and Violet mines.

The lowest level in the Foster, the 260-ft., is at the northwest corner of the property. It is reached by a winze at the north end of the long crosscut on the 210-ft. level. The 260-ft. level is of interest, as it shows there is a thickness of about 28 feet of the Cobalt series between the bottom of the Nipissing diabase sill and the underlying Keewatin.

PETERSON LAKE

Peterson Lake produced 744,343 ounces of silver. The property was not pumped out during the time of our examination of the Cobalt area. The plans of the underground workings are, however, shown on one of the plans in the pocket at the back of this report. Three vertical sections, illustrating the structure of the rocks, are shown on pages 168 and 169.

SILVER LEAF

The Silver Leaf is contiguous to and west of the Crown Reserve. The property produced 487,956 ounces of silver. It was leased to the Crown Reserve for a number of years, the lease expiring on October 15th, 1919.

The Carson vein, which produced 9,211,279 ounces of silver on the Crown Reserve, was a bitter disappointment on the Silver Leaf. The writer has not been able to ascertain how much silver it yielded in the Silver Leaf territory, but its yield was insignificant compared to that on the Crown Reserve.

The writer has not been able to obtain much information about the property and, moreover, it was not being worked during our examination. The following notes may be put on record.

In 1914, the most important development since the property was under lease to the Crown Reserve took place on the 75-ft. level, 500 feet west of No. 1 shaft, where a vein one inch wide was encountered assaying 1,000 ounces of silver per ton.

In 1915 the property gave a profit of \$16,140.41 over all expenses, and produced 84,000 ounces of silver. In 1918, one ton of high-grade and 2,216 tons of mill-rock were raised and shipped. In 1919, the net revenue was \$1,963.44, of which \$1,276.22 was due to the Crown Reserve.¹

The lowest level of the Silver Leaf is the 300-ft., which is the westward extension of the 300-ft. level on the Crown Reserve north of Kerr lake. Work was done on the extension of the North vein into the Silver Leaf property, and some ore was mined.

The 200-ft. level of the Silver Leaf is all in Keewatin, and consists of a long westward crosscut, which was not productive of results. The 130-ft. level was not examined. The 125-ft. level is a small one which is reached from the west end of the 75-ft. level; it was not examined, nor was the 100-ft. level. The 75-ft. level intersected the Nipissing diabase in three crosscuts, in the most easterly of which the contact of the diabase dips 70° to the north, an unusually steep dip. The bed of slate-like greywacké on the 75-ft. level dips at 10° to 20° to the north, but at the shaft near the east boundary it is steeper, apparently owing to a fault. The 50-ft. level of the Silver Leaf is about the same elevation as the 50-ft. level of Crown Reserve. The Carson vein splits into two branches before entering the Silver Leaf, and these two branches extend a short distance into the Silver Leaf.

¹Annual Reports of the Crown Reserve Mining Company, for the years 1914, 1915, 1918, 1919.

Geological Map of PETERSON LAKE SILVER COBALT M^{NG} C^O L^{TD} Showing Leases

Scale

1000 400 800 1200 1600 2000 FEET

LEGEND

KEWEENAWAN SERIES

 Nipissing Diabase
Intrusive Contact

COBALT SERIES

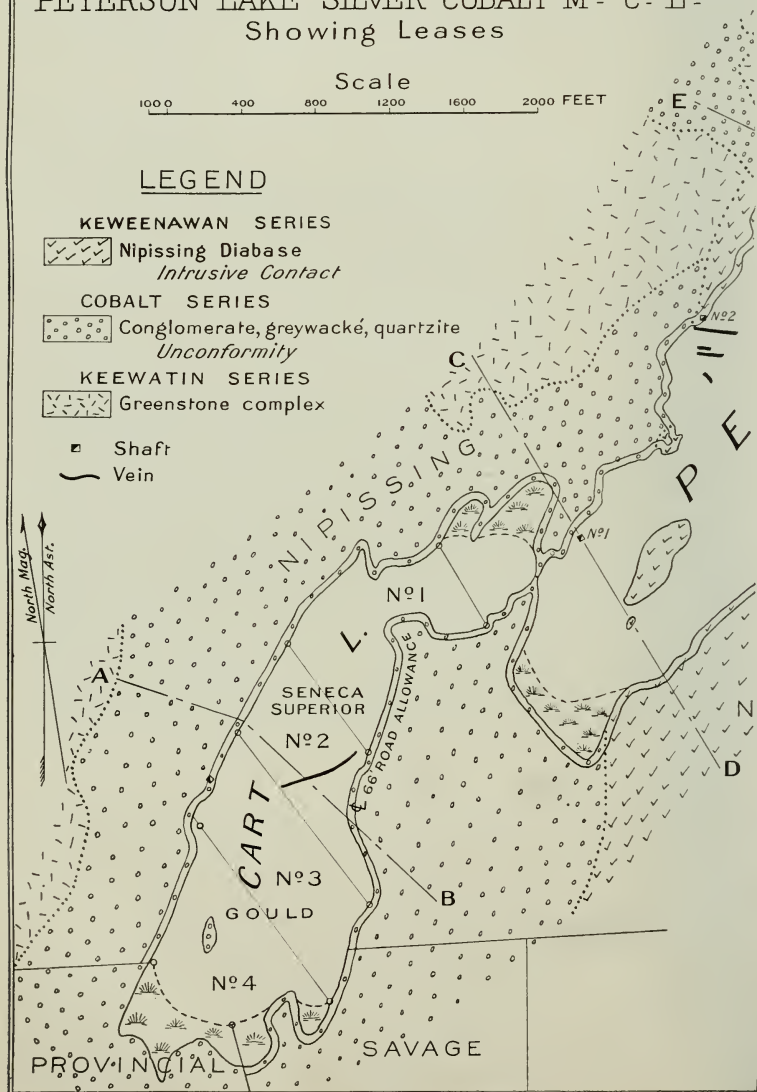
 Conglomerate, greywacké, quartzite
Unconformity

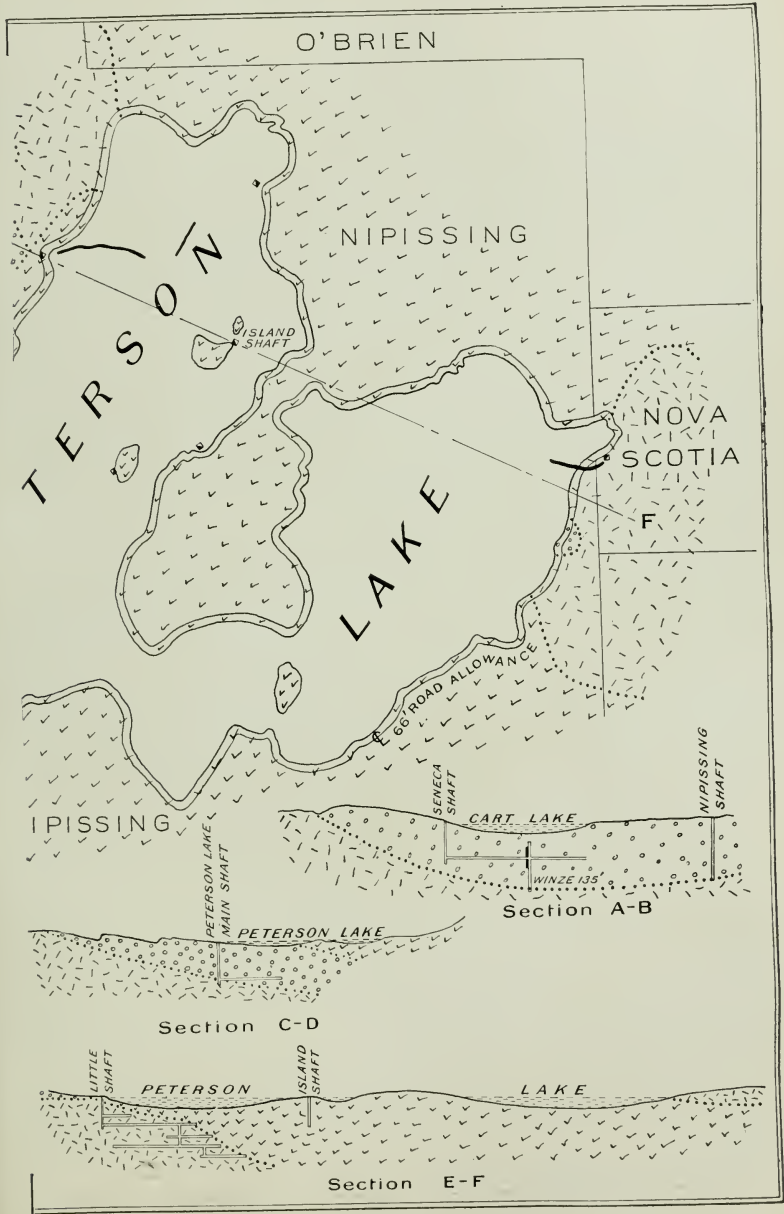
KEEWATIN SERIES

 Greenstone complex

 Shaft

 Vein





COLONIAL

The Colonial mine produced 388,681 ounces of silver to the end of the year 1921.

The writer did not have an opportunity of examining the upper workings, or those along the top of the Nipissing diabase sill. These old workings were operated largely in the earlier days of the camp, and the silver production to the end of the year 1921 has been obtained wholly from them.

More recently, a new shaft has been sunk. This shaft was completed in the spring of 1923, and on May 4th of that year the writer examined it. The location of the new shaft is shown on the plan of the Colonial workings; it was begun in the Nipissing diabase almost at the top of the sill. At a depth of approximately 960 feet below the collar, the bottom of the Nipissing diabase sill was met with. The rock below the sill is Keewatin basalt.

Near the new shaft, about 30 feet above the bottom of the diabase sill, a vein was met with in the diabase and had been followed for a short distance at the time of our examination. On the northwest face of this vein native silver in thin leaves was impregnated in the diabase, giving what was reported to be mill-rock. The vein really consisted of about a dozen calcite stringers across a width of about three feet. These calcite stringers were from a quarter to half an inch wide. One of these was an inch wide and consisted of pink calcite, together with some smaltite and a little native silver.

It was reported to the writer by Robt. A. Bryce that in subsequent operations on this vein, some high-grade silver ore was discovered.

In the fall of 1923 and the winter of 1924, some mill-rock of good grade was being shipped.

DRUMMOND FRACTION

The Drummond Fraction is at the east end of Kerr lake and comprises that part of the Drummond which is under the water of Kerr lake. There are about seven acres in the claim. The property is jointly owned by the Crown Reserve and Kerr Lake mining companies, having been purchased by these companies in 1913.

The property has produced 356,643 ounces of silver.

At the time of our examination the mine was not in operation. The following information has been summarized from the reports of the inspectors of mines for the Province of Ontario.¹

In 1913, after the lake was lowered, a high-grade vein averaging 2 inches in width was opened up on the surface for 60 feet in length. The vein was worked from the Wright shaft on the Drummond property by a crosscut which was driven from this shaft at the 100-ft. level.

In 1914, the production was derived mostly from the No. 1 vein. The output for the year was 134,256 ounces of silver, of which 95,771 ounces was from mill-rock, and 38,485 from high-grade ore.

During 1916 the property produced 40,450 ounces.

In 1917, the production amounted to 67,112 ounces, taken chiefly from a smaltite vein which is said to be the easterly extension of the Fleming vein, and also from a vein which is the westerly extension of the Comet (Drummond) vein.

Work was discontinued on January 31st, 1917.

¹Annual Reports, Ont. Bur. Mines, for years 1913, 1914, 1916, 1917.

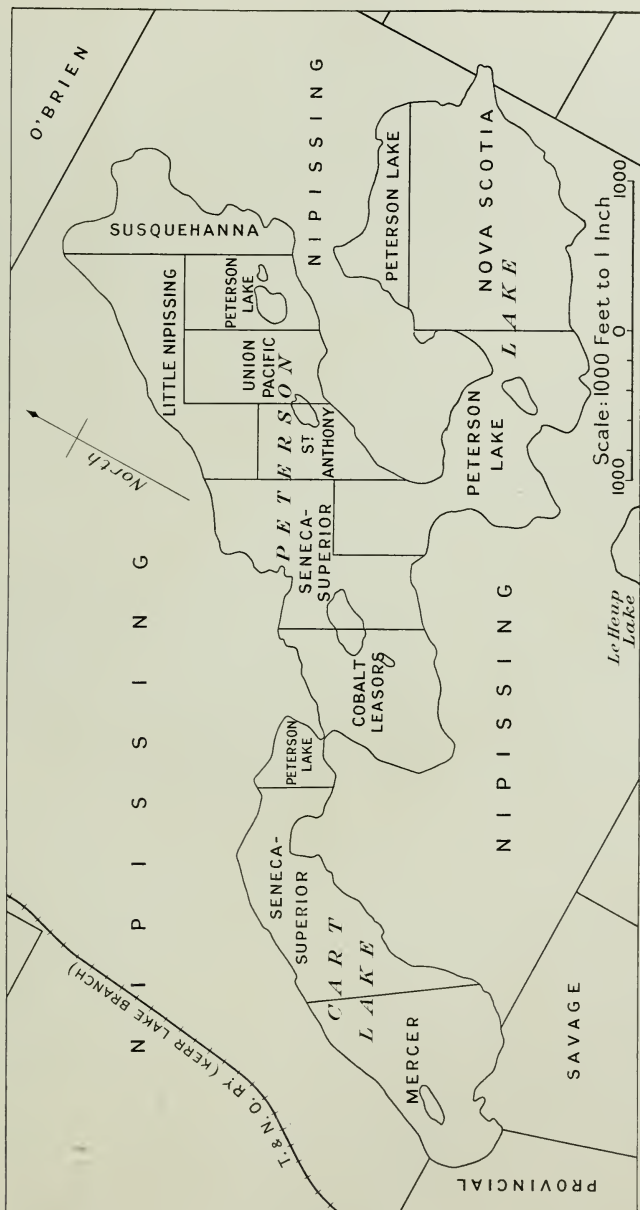


Fig. 36—Plan showing location of leases which were granted from time to time by the Peterson Lake Mining Company. These leases have since been surrendered or cancelled. The Mining Corporation of Canada, Limited, leased Cart and Peterson lakes in 1922.

BAILEY

At the time of examination in the autumn of 1920, the property was being worked by the Bailey Silver Mines, Limited.

The mine has produced 286,600 ounces of silver. The extent of the mine workings is not great, as shown on the plans of the mine. The vein-system on the property consists of an extension of the Penn-Canadian vein-system.

The structure of the rocks is about similar to that at the Penn-Canadian, as will be seen from the vertical section facing page 40. An interesting feature of the structure, however, is the manner in which the conglomerate of the Cobalt series pinches out about 400 feet west of the shaft in the long crosscut, resulting in the bed of slate-like greywacké resting directly on the Keewatin. This structure shows that there is a depression in the Keewatin which was partly filled with conglomerate of the Cobalt series. After the conglomerate was laid down, conditions of deposition changed and a bed of slate-like greywacké was deposited. Above the depression in the Keewatin, the slate-like greywacké was deposited on the conglomerate, but, along the side of the depression where no conglomerate had been laid down, the slate-like greywacké was laid down on the Keewatin floor. Similar conditions of erosion and deposition occur under Cobalt and Cart lakes.

Near the bottom of the Nipissing diabase sill, there is an almost horizontal fault showing 4 to 6 inches of fault breccia. It was stated that no ore occurs in the diabase below this fault.

PROVINCIAL

The Cobalt Provincial Mining Company, Limited, has a capital of \$1,500,000. The property has produced 245,832 ounces of silver.

The mine was worked from two shafts, one at the northwest corner of the property and the other at the east side of the property. The workings at the northwest corner of the property were in connection with the discovery of a vein made by a geological survey party of the Ontario Bureau of Mines in the year 1906. The workings at the east side are adjacent to the Savage workings, the Provincial No. 2 shaft being about 43 feet from the Savage boundary. The vein worked from No. 2 shaft is the westward extension of No. 2 vein of the Savage.

The workings at the northwest corner of the Provincial mine were flooded at the time of the examination in August, 1921, so that an examination could not be made.

Part of the workings at the east side were being kept dewatered to within a few feet below the 175-ft. level. The No. 2 shaft in this part of the mine is reported to be 350 feet deep, and the levels are at the following elevations below the collar of the shaft, namely, 100-ft., 175-ft., 217-ft., 300-ft., and 350-ft. The shaft was sunk on a calcite vein, and it is reported that the vein continued vertically to the bottom of the shaft. When the vein passed into a 20-ft. bed of slate-like greywacké below the 175-ft. level, it became irregular and patchy. The bottom 100 feet of the vein was reported to consist of pure smaltite, 8 inches wide in places, assaying 2 to 40 ounces of silver. We were able to examine the vein in the shaft from about the surface down to the 175-ft. level, and found it to be a strong calcite vein 1 to 3 or more inches wide.

The Cobalt series has a thickness of approximately 350 feet in the No. 2 shaft, the contact between the Keewatin and Cobalt series having been found at about that depth in the shaft by Mr. John Redington.¹

¹Private communication from Mr. John Redington.

The rocks in the shaft consist of conglomerate and greywacké, with the exception of two beds of slate-like greywacké, one of which is about 4 feet thick just above the 175-ft. level, and the other about 20 to 25 feet thick at about the 217-ft. level.

The Cobalt series rests in a deep erosion valley carved in the old Keewatin. This Keewatin valley strikes northeastward along the bed of Cart lake. The eastern side of the valley is extraordinarily steep, dipping as it does to the north-westward at an angle of about 50° or more (Fig. 37). The bottom of the valley was first filled with conglomerate, upon which a bed of slate-like greywacké was later deposited. The sediments were laid down in such a way that the conglomerate filled the bottom of the valley, and the slate-like greywacké was deposited directly on top of the Keewatin on the upper sides of the valley, but on top of the conglomerate which filled the bottom of the valley (Fig. 37).

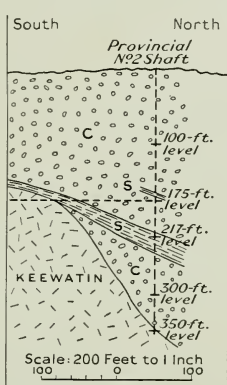


Fig. 37—Vertical section through the Provincial mine showing deep basin in Keewatin; a bed of slate-like greywacké rests directly on the Keewatin on the side of the basin, and on conglomerate in the middle of the basin.

S—Slate-like greywacké.

C—Conglomerate.

The property was examined by Mr. James Hill in 1921, and the writer also spent part of a day in the same year in company with Mr. John Redington. A description of the two accessible levels, based on information furnished by James Hill and John Redington, is given below.

175-ft. Level, No. 2 Shaft.—The vein on this level is the westward extension of No. 2 vein on the Savage. It has been stoped for 160 feet. There is a parallel vein which has been stoped for 35 feet. The larger stope connects with the stope on the Savage. The two veins unite a few feet west of the Provincial shaft. A calcite stringer crosses the vein about 40 feet west of the shaft, and at this intersection the richest ore was said to have been obtained.

About 165 feet southwest of the shaft, the vein encountered a minor fault showing an inch or two of fault breccia and dipping about 65° eastward. To the west of this fault the vein is very small, consisting of a crack with an eighth of an inch of calcite. About 40 feet west of the fault the vein pinches out.

All of the level consists of the Cobalt series, except the south part of a crosscut running south of the shaft. In this crosscut, about 120 feet south of the shaft, a bed of slate-like greywacké a few feet thick rests directly on Kee-

watin. The slate-like greywacké has ripple marks. The crosscut was driven in Keewatin for some distance, as shown on the plan. At the south end of the crosscut, there is an inclined raise showing the steep dip of the Keewatin floor.

The bed of slate-like greywacké was also met with in the shaft at the 217-ft. level where it is much thicker; it was also encountered at the southwest end of the long crosscut which extends southwestward from the No. 2 shaft on the 175-ft. level.

A long crosscut extends northwest from No. 2 shaft to the northwest part of the property. This crosscut was inaccessible owing to a dam near the No. 2 shaft; it was stated, however, that the crosscut was wholly in the Cobalt series, except at the north end where the Keewatin was encountered.

100-ft. Level, No. 2 Shaft.—The vein is stoped westward from the shaft for 70 feet; in the west face the vein varies in width from one to four inches. The ore does not extend to the surface. The level is all Cobalt series.

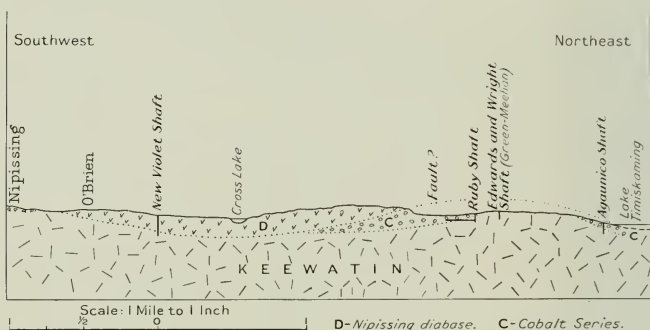


Fig. 38—Vertical section showing relation between the Nipissing diabase sill and underlying rocks at Nipissing, O'Brien, Violet, Ruby, Edwards and Wright (Green-Meehan), and Aganico. Since this vertical section was drawn, subsequent operations at the Ruby, early in 1924, proved the existence of a major fault at the spot marked "Fault?". Vertical scale slightly exaggerated.

EDWARDS AND WRIGHT (GREEN-MEEHAN AND RED ROCK)

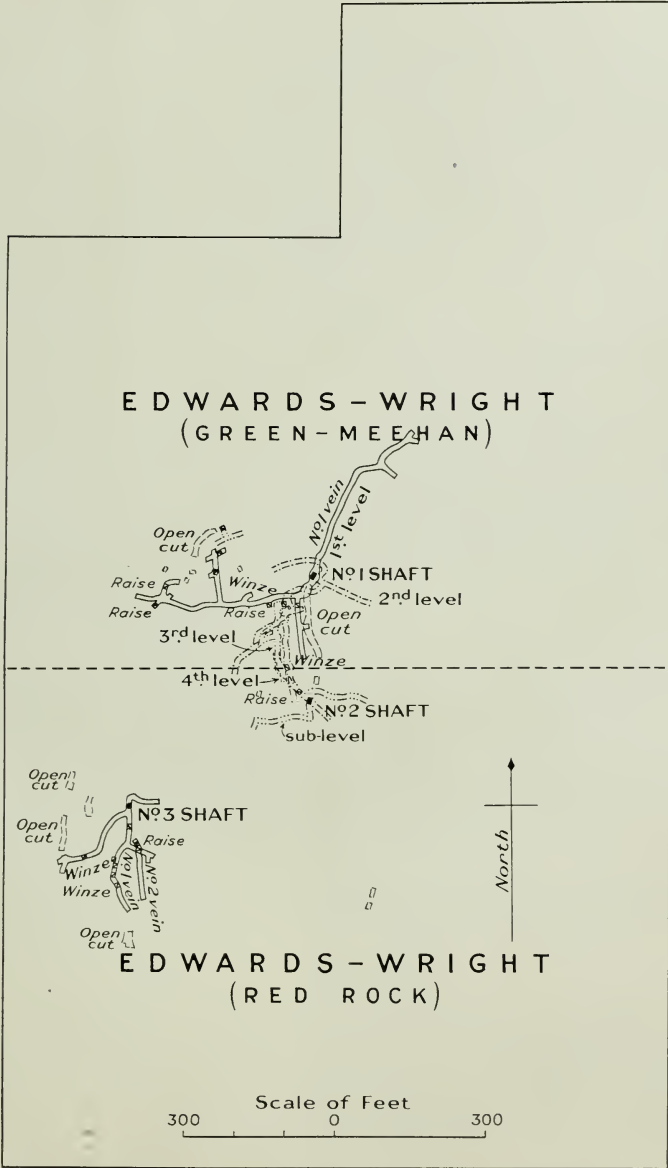
Edwards and Wright, Limited, was incorporated on January 30th, 1918, with a capital of \$100,000. The company worked the old Green-Meehan and Red Rock properties for a number of years.

To Major Ward Wright, who operated the Green-Meehan in recent years, belongs the credit for keeping alive interest in this section of the Cobalt silver area.

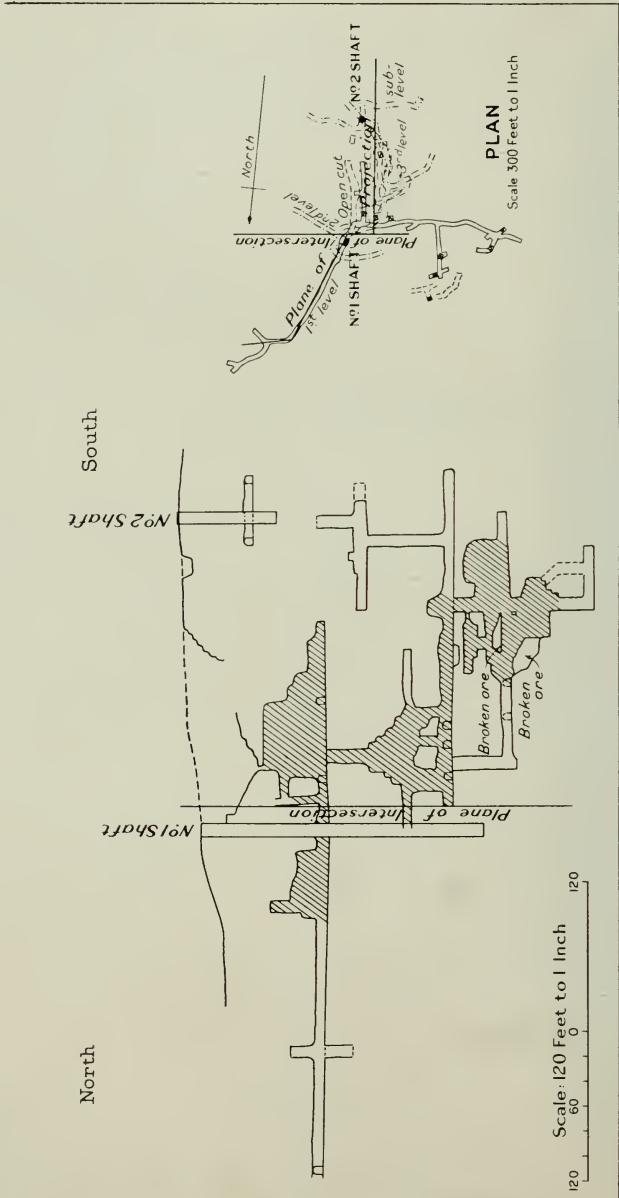
The Green-Meehan has produced 223,629 ounces of silver. There are a number of veins on the property, chief of which is the No. 1 vein on which most of the work has been done. Vein No. 9 also produced some ore from an open pit. The veins are all in Keewatin rocks.

A shaft has been sunk on the No. 1 vein to a depth of 200 feet with levels and sub-levels. The No. 1 vein is a strong calcite one in which half a dozen small ore-shoots have been discovered. The vein strikes about north and south and dips at an angle of about 75° westward. The trend of the ore-shoots is 35° southward.

There are a number of minor faults in the workings, one of which dips at an angle of about 35° to the south.



Plan showing mine workings of Edwards-Wright (Green-Meehan and Red Rock Mines)



Stope section on Edwards-Wright (Green-Mechan).

The general relationships of the rocks at the Green-Meehan to the rocks in the main productive area in Cobalt, are shown in the vertical section (Fig. 38). At the south end of the Red Rock the Nipissing diabase occurs; it rests on top of the Keewatin and dips eastward towards Lake Timiskaming and westward towards Cobalt, forming a gentle dome. The No. 1 vein on the Green-Meehan occurred below the dome. Of course that part of the diabase above the No. 1 vein has long since been eroded. Possibly the vein extended upwards into the diabase and may have contained rich shoots.

The Red Rock is contiguous to the Green-Meehan on the south. The rock consists mostly of Keewatin basalt, but there are a few patches of conglomerate of the Cobalt series on the west side of the property. These conglomerate patches are only some 10 or 15 feet thick. There are three shafts on the property 35, 75, and 110 feet deep. A number of calcite veins were found, characterized by the presence of copper pyrites.

Some of the veins on the Green-Meehan, Red Rock, and Ruby are characterized by the presence of unusual quantities of copper pyrites.

LITTLE NIPISSING SILVER MINE

The Little Nipissing property at Short lake is south of the Princess mine. The plans of the mine levels are shown on sheet No. 31a-13. Considerable exploration work was done on the property by the Mining Corporation, and while some patches of ore were found in the Cobalt lake fault, the results were not sufficiently encouraging, and operations ceased in the autumn of 1917.¹

The Little Nipissing at one time held a lease of part of the northwest corner of Peterson lake (Fig. 36). This area produced 83,108 ounces of silver. The lease was later surrendered.

MERCER

Mr. W. E. Segsworth very kindly furnished the Ontario Department of Mines with the following information regarding the Gould Consolidated or Mercer mine, which is immediately southwest of the Seneca-Superior.

The adjoining lease to the southwest was operated successively by the Gould Consolidated and Mercer Mining Companies. As previously indicated, the southwest end of the Worth ore body extended into this property 50 to 60 feet. From the Worth vein the Gould Consolidated produced 60,220.8 ounces of silver and the Mercer 81,998.41 ounces, or 142,219.24 ounces of silver in all. This, added to the production from the Seneca, gave a total production of 5,781,312 ounces from the Worth vein.

It may be added that in 1922 the Mining Corporation of Canada, Limited, leased Peterson and Cart lakes, pumped out the Seneca workings, began stoping the low-grade ore in the winze, and commenced exploration for further ore bodies.

ADANAC

The Adanac Silver Mines, Limited, operated claims in the southeast corner of Coleman township contiguous on the west to the Temiskaming mine. The company was incorporated on May 15th, 1915, with a capital of \$2,500,000, and acquired claims formerly known as the Pan-Silver and Calumet. No large ore-bodies have been discovered, but some small shoots of high-grade silver ore were met with and some shipments of mill-rock were made. The company produced 28,057 ounces of silver.

¹Fourth Annual Report, Mining Corporation of Canada, Limited, for year 1917, p. 23.

At the time of examination, in July, 1921, the only accessible shaft was the Patterson, at the southeast corner of the workings. From this shaft there are seven levels which are 100, 200, 267, 300, 310, 321, and 400 feet below the collar of the shaft. The 310-ft. and the 267-ft. levels are reached by way of winzes.

James Hill examined the 100-ft., 200-ft., 300-ft., and 310-ft. levels in 1921 for the Ontario Department of Mines; at that time the water was a few feet below the 310-ft. level. The information given below concerning these levels is based on Mr. Hill's notes.

310-ft. Level.—The workings in the south half of the level are in Keewatin basalt. In the long drift running northward, the Nipissing diabase was met with dipping 18° to the southward. This long drift follows for 1,050 feet a small calcite vein from a quarter of an inch to two inches wide. Near the south end of the vein, where it branches, there is a stope about 115 feet long and 15 to 20 feet high.

300-ft. Level.—This level is all in Keewatin which is cut in places by lamprophyre in the vicinity of the shaft. A calcite vein about an inch wide occurs in the drift in which the winze has been sunk. There are no stopes on this level.

200-ft. Level.—The level is also in Keewatin rocks cut by lamprophyre dikes. East of the shaft there is a small stope 16 feet long and 15 feet high; the vein contains a little smaltite and niccolite.

100-ft. Level.—This level, which is a short one, is in Keewatin rocks. About 90 feet west of the shaft there is a vein of quartz eight feet wide.

LUMSDEN

At the time of examination, in October, 1920, the Lumsden mine was being operated by the Camburn Silver Mines, Limited, Major J. H. Rattray in charge. The Lumsden mine has produced 21,088 ounces of silver, which was obtained largely from the Keewatin.

The shaft was sunk in Keewatin and encountered the Nipissing diabase at a depth of about 290 feet.

The main vein-system strikes a little east of north and occurs a few feet east of the shaft. There are also two intersecting veins near the southeast end of the long crosscut on the 300-ft. level; and there is a vein called the "Vimy Ridge" on the 250-ft. level.

300-ft. Level.—The station at the shaft is in Nipissing diabase; about 50 feet south of the shaft the Keewatin was met with; the long southeastward crosscut is entirely in Keewatin rocks.

The vein-system a few feet east of the shaft consists of 3 or 4 parallel veins which split at a point about 100 feet south of the shaft. Some of these veins contain quartz.

Near the end of the long crosscut at the southeast end of the property, there are three veins at the junction of which a winze 20 feet deep had been sunk. On October 28th, 1920, the winze was 20 feet deep. A small patch of high-grade silver ore was reported to have been met with at the intersection of these veins.

250-ft. Level.—A few feet east of the shaft there is a quartz vein, about 6 inches wide, containing some calcite.

About 235 feet east of the shaft, a vein called the "Vimy Ridge" was met with and drifted on for over 200 feet; it was found to be a strong though irregular vein. About 90 feet east of the "Vimy Ridge" vein, the top of the Nipissing diabase sill was met with dipping southwestward about 22° . The crosscut was

continued eastward into the Prince as far as its east boundary, and the rock was found to consist of Nipissing diabase. About 100 feet west of the east boundary of the Prince, there is a dike of fine-grained basalt cutting the Nipissing diabase. This dike is 12 or 15 inches wide and strikes 10° or 20° east of south. It resembles the small basalt dike on the 383-ft. and 499-ft. levels of the Temiskaming mine, and may be the northwest extension of the Temiskaming dike.

225-ft. Level.—The main vein on this level consists of a quartz vein 2 to 12 inches wide. A calcite vein follows this quartz vein. In some places the calcite vein is in the quartz vein; in other places it follows the wall of the quartz vein, and in still other places it may be 1 or 2 feet from the quartz vein. About 85 feet south of the Nipissing diabase, the quartz vein enters the wall of the drift and is not seen again. The calcite vein continues north to the diabase, where it splits into half a dozen calcite veins less than an inch in width. Native silver occurs in the quartz vein and in the calcite.

ROCHESTER

The Rochester mine was flooded at the time of examination. It produced 13,459 ounces of silver.

The plans of the levels are shown on a map in the pocket at the back of the report.

RUBY

The Ruby produced 8,702 ounces of silver to the end of the year 1922. During the years 1922 and 1923 it was under option to the Coniagas Mines, Limited. This company put down three diamond-drill holes. In the No. 1 hole, a four-inch vein of much promise was discovered; the vein contained mostly calcite, together with a little smaltite and copper pyrites. A sample of the vein in the core was found to assay 375 ounces of silver per ton.

The Ruby property is almost entirely covered with drift, and this diamond-drilling was done in the heavily-covered portions. In the drill hole which discovered the calcite vein, the drift was found to be about 50 feet deep, and, much to the surprise of every one, the Cobalt series was found to be about 160 feet deep.

The Coniagas management established a level at 150 feet in the shaft at the east side of the Ruby property and ran a crosscut about 1,000 feet westward. The vein which was cut in the diamond-drill hole was intersected in this long crosscut. Other veins were also found at the west end of the crosscut. These calcite veins contained native silver, ruby silver, and smaltite. In the summer of 1923 and early in 1924, they were being explored by the Coniagas management. A shoot of cobalt ore, 150 feet long and five or six inches wide, carrying small patches of native silver, was discovered.

The long crosscut referred to in the above paragraph was in Keewatin basalt for 446 feet west of the shaft, where the Cobalt series was met with. The Cobalt series consisted of coarse greywacké and fine conglomerate. One pink granite boulder 3 or 4 feet long was noted in the conglomerate, but the latter rock is for the most part made up of small pebbles.

Prior to the time when the Coniagas mine obtained an option on the property, a little work had already been done in some veins at the shaft. It was found that the conglomerate of the Cobalt series had a thickness of but 15 feet in the shaft, below which was the Keewatin. These workings had a depth of about

100 feet. Some shipments of good mill-rock had been made from a winze which was sunk from the 65-ft. level of the shaft. This ore was all obtained from the Keewatin in an irregular calcite vein; some of the silver was in the wall-rock.

On the surface, just southeast of the shaft, a calcite vein about an inch wide containing some smaltite was encountered. This vein may be seen at the present time in a shallow trench.

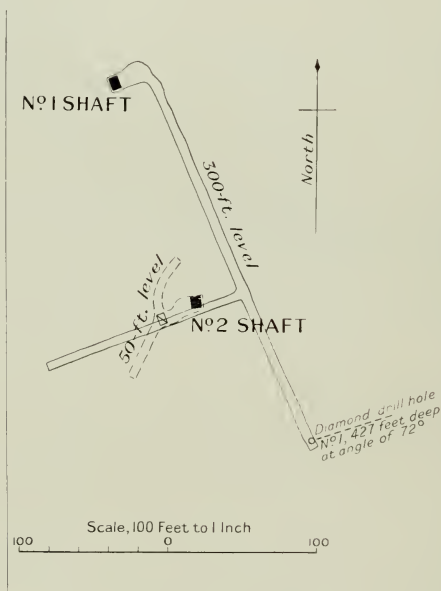


Fig. 39—Plan showing workings in North Cobalt mine, the southwest quarter of the north half of lot eleven, in the second concession, Bucke township.

NORTH COBALT MINE

The North Cobalt property, consisting of 40 acres, is located on the western outskirts of the town of North Cobalt. The claim is the southwest quarter of the north half of lot eleven, in the second concession of the township of Bucke.

The workings are shown on the plan (Fig. 39). They were not accessible during the time of our examination. Through the courtesy of the Mining Corporation of Canada, the writer was informed that the No. 1 shaft was sunk in Nipissing diabase to a depth of 300 feet. From the south end of the main crosscut, which is in Nipissing diabase, a diamond-drill hole was put down 427 feet at an angle of 72° to the eastward. The hole is reported to be entirely in Nipissing diabase.

The workings and drill hole thus show that the Nipissing diabase has a thickness of at least 700 feet in this area.

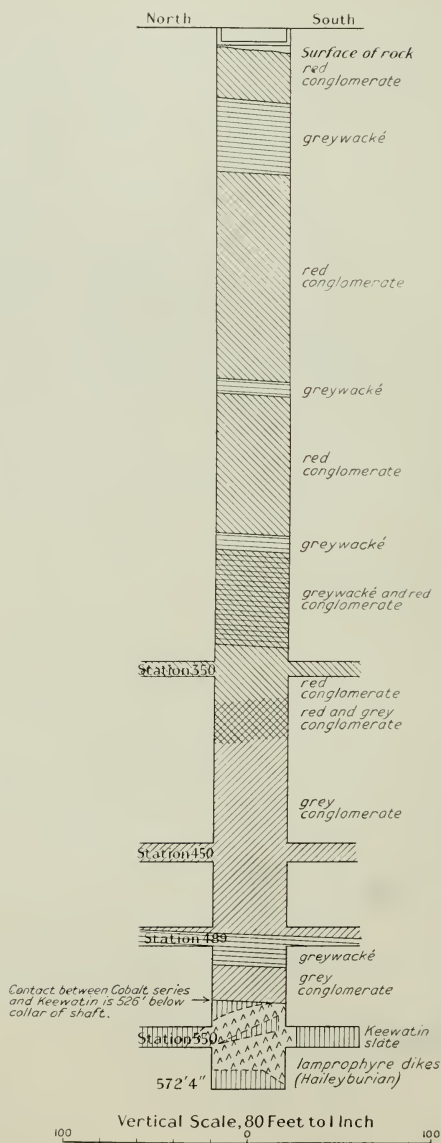


Fig. 41—Section by L. F. Steenman, showing rocks in Genesee shaft. The Cobalt series has a depth of 526 feet.

Beginning with the bottom level the following notes may be put on record.

500-ft. Level.—As stated above, this level was not accessible at the time of our examination, and the Department is indebted to Mr. Steenman for the following information. The Keewatin consists of a grey slate, dipping about vertically and striking eastward; samples of this rock may be seen on the dump. The slate in these samples from the dump is cut by mica-lamprophyre. It is stated that a few pebbles were found in the slate. Four veins were encountered, namely, Nos. 2, 3, 4, and 6. Vein No. 3 is reported to occur in a major fault, and a little silver is said to have been found in it.

450-ft. Level.—At the north end of the level, grey Keewatin slate was met with in three crosscuts (Fig. 40). The slate dips almost vertically and strikes eastward; it resembles the Keewatin slate in the deep bay of Sasaginaga lake just west of the Trethewey mine. The contact between the slate and Cobalt series is sharp and knife-like.

At the north end of the workings a small vein, No. 10, less than an inch in width, was met with. A sample of the mineral from this vein was submitted to W. K. McNeill, Provincial Assayer, and found to be cobaltite. This vein was met with in the workings just about at the contact between the Keewatin and Cobalt series.

350-ft. Level.—This level is all in the Cobalt series. Five veins were discovered, Nos. 8, 9, 10, 11, and 12. Vein No. 10 is about three-quarters of an inch in width, consisting of pink calcite; a little high-grade silver ore is reported to have been found in this vein. Vein No. 8 is 1 to 2 inches wide, consisting of pink calcite; it was not met with on the level below, the 450-ft. Vein No. 9 is also of pink calcite, about half an inch in width.

In the fall of 1923, vein No. 11 was discovered on the 350-ft. level, a short distance north of vein No. 10. Vein No. 11 strikes about east and west and averages about three inches in width. It was from this vein that the production was obtained.

OXFORD COBALT

The Oxford Cobalt Silver Mines, Limited, has been doing some pioneer work between Giroux and New lakes, about a mile west of the Temiskaming mine; these operations are being carried on by J. W. Russell. The property was examined in August, 1921, and the following information was then obtained.

In the spring of 1921 a small vein of smaltite, about half an inch wide, was discovered on the northeast part of lot No. A. 99. The vein occurs in Keewatin basalt, about 100 feet south of the Nipissing diabase. In this section the diabase dips under the Keewatin. A shaft was sunk on this vein and had reached a depth of 40 feet.

The company was also operating claim C. 1000, which is directly southeast of A. 99. Although the company had, in the summer of 1921, ceased operations on this lot, they had previously sunk a shaft to a depth of 150 feet. The shaft followed a pink, bright-coloured, fine-grained felsite dike, which, at a depth of 37 feet, passed out of the shaft. This dike strikes east 20° north and dips steeply to the northwest. On the 150-ft. level a crosscut was driven 35 feet, where the pink felsite dike was encountered. It was drifted on for 60 feet northeast of the crosscut, and the dike still showed in the face. It was also followed for 20 feet to the south-westward, at which point it was cut off by a prominent joint plane in the rock. A crosscut, 10 feet southeast and 15 feet northwest, failed to locate the extension of the dike.

The dike varies in width from an inch or two to about a foot and may average three or four inches. Here and there, sparingly, the dike contains galena, zinc blende, pyrrhotite, copper pyrites, calcite, epidote, and quartz.

The shaft was sunk in Keewatin basalt. It is difficult to estimate the depth at which the top of the Nipissing diabase sill may be below the surface where the shaft was sunk. But, from the depth at which it occurs at the Beaver, Temiskaming, and Adanac properties, a hint may be obtained as to its possible depth at the Oxford Cobalt.

Since the above information was obtained, Mr. Russell reports that further work has been carried on at the property.

VICTORY

The Victory Silver Mines Company, Limited, has been operating for the past two or three years a 10-acre claim north of the Ophir in southeast Coleman. The writer examined the property in August, 1921, and found that the shaft was down to a depth of 185 feet where a station had been cut and a crosscut driven westward. On August 13th the face of the crosscut was 120 feet west of the shaft. The crosscut encountered a vein of quartz and calcite containing galena, zinc blende, and copper pyrites; this vein is an inch or two in width. Two or three other stringers of calcite, fractions of an inch wide, were also encountered. All these veins strike about north and south and have a vertical dip. No native silver was noted in these veins at the time of examination.

On the 100-ft. level, there was a drift about 25 feet long, following a calcite and quartz vein an inch or two wide. The vein strikes 10° or 15° west of north.

On the 40-ft. level, no drifting had been done, but the shaft had originally been sunk on an incline, following a small calcite vein which, at the 40-ft. level, was less than an inch wide. Later on the shaft was sunk vertically and the inclined upper part made vertical also.

The shaft is about 150 feet south of the north boundary of the claim.

The rock encountered in all the workings is Keewatin basalt. There is a two-inch dike of pink granite in the crosscut on the 185-ft. shaft.

Since the above examination was made, further work has been done, and the writer has been informed that a little high-grade silver ore has been found. The shaft has been sunk to a depth of 450 feet. Through the kindness of the company, the writer was furnished with a report by J. A. MacVichie, the mine manager. The following information is summarized from this report, which is dated November 15th, 1922.

In sinking the shaft a calcite vein was encountered at a depth of about 300 feet, striking north 33° west and dipping 56° northwestward. The vein left the shaft about 21 feet below where it was first met with. It had a width of two to ten inches and contained smaltite and native silver. The report states that: "From the second round we had an assay of silver, 1,676 ounces per ton."

On the 450-ft. level ten veins were said to have been met with, most of them small niccolite and smaltite ones. Vein No. 3 was as wide as 17 inches of calcite and was said to contain some small "spots" of native silver. Vein No. 3 was also said to be wide and to contain some smaltite and "low values" in silver. Veins Nos. 1, 2, 3, and 5 strike northwestward, while Nos. 4, 6, 7, 8, 9, and 10 strike northeastward.

AGAUNICO

The Agaunico mine is situated on the shore of Lake Timiskaming about a mile south of the town of Haileybury. The property has not been productive of silver, but a strong vein of cobalt ore was discovered in the early days of the camp. This vein, which occurs in a fault, has had some stoping done on it.

The writer examined the property in the spring of the year 1920. There is a shaft 400 feet deep. The Cobalt series in this shaft has a thickness of 210 feet. Below this, the rock consists of fine-grained Keewatin basalt to the bottom of the shaft. At the bottom of the shaft, however, there is a soft, schistose dike of mica-lamprophyre. It dips westward and leaves the shaft 25 feet above the floor on the northeast side of the shaft. About four-fifths of the floor is composed of the lamprophyre.

The Keewatin basalt in the shaft contains many pink and white calcite or dolomite stringers, usually less than half an inch wide and a foot or two long. There are also some quartz veins, a few inches wide, in the Keewatin and in the lamprophyre dike. At the bottom of the shaft these quartz veins have a bluish colour.

Some interest was aroused in the Agaunico about the years 1918 and 1919 by the finding on the dump of a dozen or more specimens of a bluish-white quartz containing some native gold. These specimens were all about the size of a man's fist and somewhat resembled the quartz veins in the bottom of the shaft. The rock attached to the specimens was apparently Keewatin basalt; no mica-lamprophyre was noted. In an effort to discover where these rich gold specimens came from, the shaft was systematically sampled in the year 1920 by the owners, and about 100 samples were taken. Most of these samples were blanks, or assayed less than one dollar per ton of gold. It may be added that a careful examination of the quartz stringers in the shaft failed to discover any native gold.

Regarding the cobalt vein, referred to above, the following notes may be put on record. The vein strikes northeastward and dips steeply to the northwest. It occurs in a reverse fault, the displacement of which is probably less than four or five feet. There is a fault breccia, which is in places two feet wide. On the 200-ft. level, the vein is about 60 feet northwest of the shaft. It has been stoped more than 100 feet in length and some 25 feet in height. The vein on the 200-ft. level dips at 80° to the northwest. It varies in width from an inch to six or eight inches; it contains niccolite in places, in addition to cobalt ore.

At the base of the Cobalt series, there is a bed of conglomerate about 10 feet thick, above which is a bed of slate-like greywacké several feet thick. The crosscut on the 200-ft. level from the shaft to the vein follows this bed of greywacké.

On the 55-ft. level the vein has been stoped for a length of over 50 feet and is as wide as eight inches.

PRINCE

The work done on this property consists of a westward crosscut from the 1,400-ft. level of the Beaver mine, and a northwestward drift following a vein on the same level. This vein on the 1,600-ft. level of the Beaver is reported to have produced 40,000 or 50,000 ounces of silver. These workings on the Prince are shown on the plans of the 1,400-ft. level of the Beaver mine.

Some work was also done on the Prince from the 300-ft. level of the Lumsden mine. This work consisted of a crosscut running eastward across the claim to the west boundary of the Temiskaming mine. Near the Temiskaming line a crosscut was run to the south. These two crosscuts are in Nipissing diabase.

The Prince was under option in the year 1923 to the Coniagas.

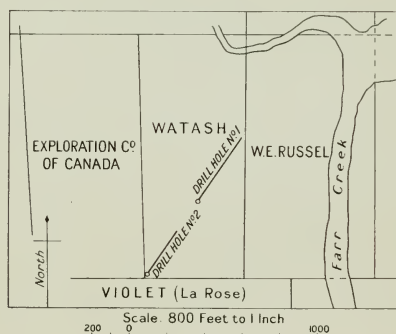


Fig. 42—Plan showing location of diamond-drill holes on Watash.

WATASH

The Watash property lies north of the Violet (Fig. 42). The writer is indebted to T. R. Jones for the following information concerning the diamond-drilling which has been done on the claim.

Two holes were drilled, the location of which is shown on the plan. Hole No. 1 dips at an angle of 45° to the northeast and is 600 feet deep. After cutting through 12 feet of soil, the hole is reported to pass through conglomerate for the rest of its depth, except between 360 and 380 feet which is reported to be diabase.

Hole No. 2 also dips at an angle of 45° to the northeast, and, after passing through 71 feet of soil, is reported to have passed through diabase to a depth of 320 feet, after which conglomerate was encountered to a depth of 421 feet.

The measurements given are along the dip of the holes.

OPHIR AND PEOPLE'S SILVER

The Ophir and the People's Silver mines in the southeast part of the township of Coleman were not accessible. Fig. 43 shows the plans of the levels.

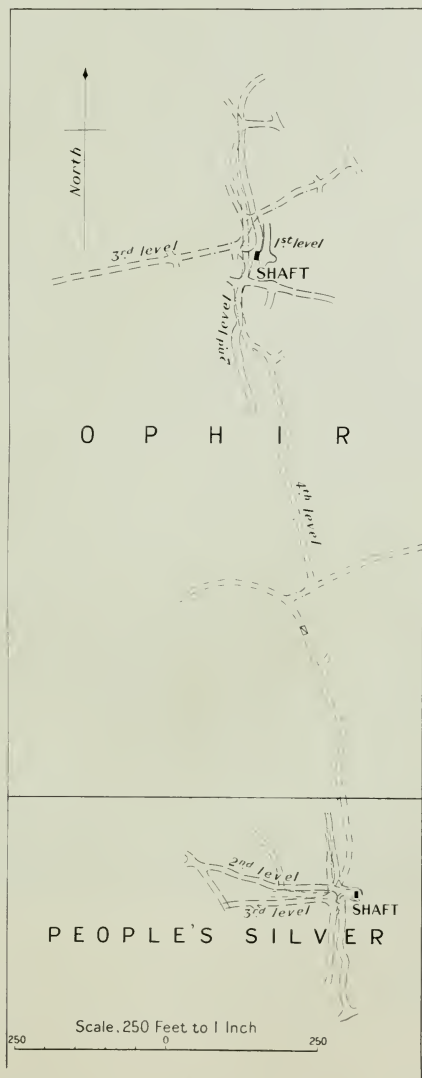


Fig. 43—Plans of mine levels of Ophir and People's Silver.

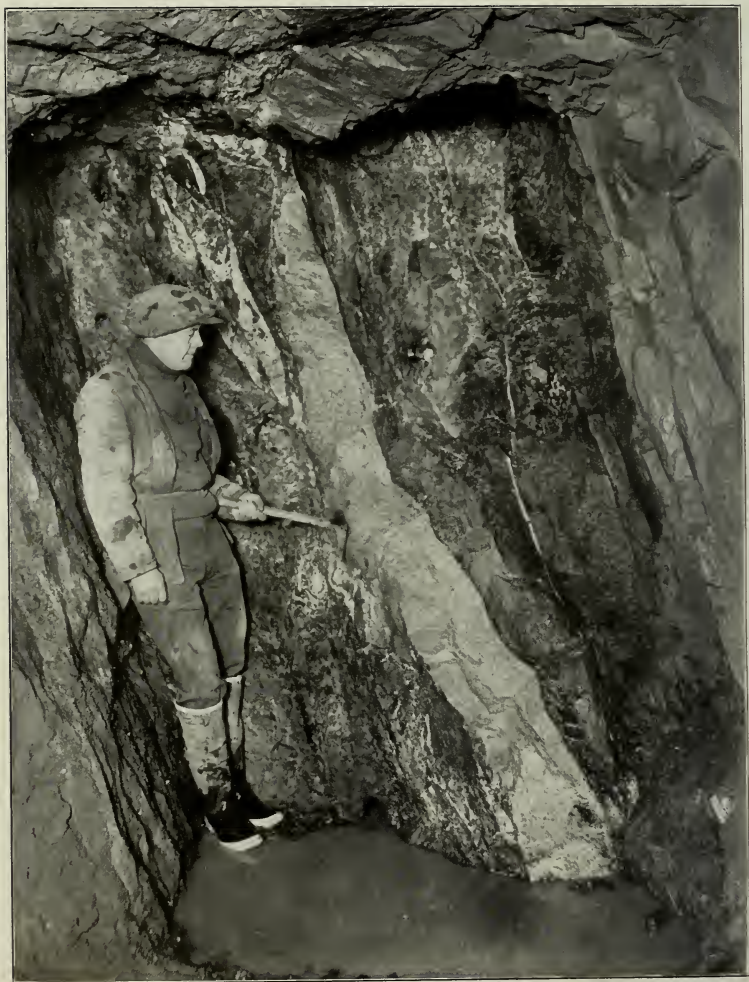


Fig. 44—Wood's vein, north face, Keeley mine, 480-ft. level, October 12th, 1922. The vein averages 10 inches in width and assays 8,000 to 14,800 ounces of silver per ton. This ore is in the Nipissing diabase sill, about 50 or 60 feet below the top of the sill. Leonard G. Smith at the left. Photographed by Cyril W. Knight.

CHAPTER III

SOUTH LORRAIN

INTRODUCTION

The productive part of the South Lorrain silver field occupies a comparatively small area, probably less than one hundred acres. It is sixteen miles southeast of the town of Cobalt. The field may be reached by a road from Cobalt, or by a pleasant twenty-mile trip on a steamboat from the town of Haileybury down Lake Timiskaming. From the wharf at South Lorrain it is about three miles westward over a rough road to the Keeley, Frontier, and Wettlaufer mines.



Fig. 45—Plan showing relative position of South Lorrain.

South Lorrain at the present time is attracting much attention owing to rich silver ore-shoots which have been discovered at the Keeley and Frontier mines during the last two years. As a result it is certain that much new exploration will be carried on, with the object of ascertaining whether the present small productive area can be enlarged.

The field was examined in the fall of 1921 and 1922, and brief visits were also made in January and May, 1923. In the year 1922 there were only two operating companies, namely, the Mining Corporation of Canada, Limited, working the Frontier, and the Keeley Silver Mines, Limited, operating the Keeley.

The history of South Lorrain has had its tragic and romantic aspects, its ups and downs. Silver was discovered in 1907 at the Keeley mine, and there followed a period of widespread staking of claims, and of active work lasting until the latter part of the year 1913. During this time, which may be called the first period in the history of the camp, there were produced about 2,446,235 ounces of silver, practically all of which came from the Wettlaufer mine. The Keeley yielded 24,337 ounces, according to the official records of the Ontario Department of Mines.

The camp then became almost inactive for eight years, and was looked upon with little interest by most mining men during that time. To all intents and purposes it was a dead camp.

The credit for the rejuvenation of South Lorrain is due to Dr. J. Mackintosh Bell. He obtained an option on the Keeley mine in 1913, and after efforts lasting for eight years finally succeeded in 1921 in finding rich ore-shoots. South Lorrain thereupon entered the second period of its history, and now gives promise of developing, for the time being at any rate, into the most important of the outlying areas of the entire Cobalt silver camp.

In the rejuvenation of the area Horace F. Strong also played a prominent part. He discovered the first important high-grade ore at the Frontier mine in August, 1921, and through his agency the Mining Corporation of Canada, Limited, acquired this property. J. G. Harkness, who had spent much time in South Lorrain, was associated with Strong in the early development of the Frontier. On following pages are described conditions that militated against the earlier development of the Frontier.

Most people in northeastern Ontario are familiar with the rôle which the Farmers Bank played in the early history of the Keeley mine. The bank was indirectly and vitally interested in the property, and became insolvent partly as a result of the failure of the mine to produce the anticipated quantity of silver for which the promoters of the mining venture hoped. Let this be said for the Farmers Bank: Had the operators known the relation of ore-shoots to the diabase contact, it is probable that the rich ore-shoots along the top of the Nipissing diabase sill would have been found by the early promoters. In view of the high-grade ore which has been discovered recently at the mine along the top of the diabase sill at a depth of 400 to 500 feet, it would appear that the early promoters were justified in their venture. They failed through what would popularly be called hard luck.

The silver veins of the productive area of South Lorrain outcrop on the height-of-land between the Montreal river and Lake Timiskaming, 500 to 600 feet above the lake. The deposits are just over the crest, on the west side of the divide facing the valley of the Montreal river. The country is rugged and generally barren of soil, except in the valley of the river and in isolated spots elsewhere. Along the river valley there are picturesque stretches of agricultural land, fringed by rocky hills, which some day will be turned into as beautiful a bit of farm land as is to be found anywhere in northeastern Ontario. It is desirable that this land be settled now, as a market for farm produce is available at the nearby mines.

A. G. Burrows reported on the South Lorrain area in 1909, his report being based on work carried out in 1908.¹ The surface geology of South Lorrain and also of part of Lorrain township was mapped by A. G. Burrows, James Bartlett, and R. B. Stewart. The accuracy of their work has been acknowledged and appreciated by mine operators and prospectors alike. Burrows

¹Ont. Bur. Mines, Vol. XVIII, pt. II, 1909.

found that the formations conformed to the scheme of classification worked out by Willet G. Miller for the Cobalt area proper. When Burrows reported on the area little actual mining had been done, and hence his report did not deal with the geological structures of the rocks and veins at depth. More recently, in 1922, Dr. J. Mackintosh Bell¹ has written a report on South Lorrain, dealing particularly with the Keeley mine.

The writer is greatly indebted to Dr. J. Mackintosh Bell, and to his associates, Messrs. H. Whittingham and Leonard G. Smith, for much information regarding the Keeley and Maidens mines. Dr. Bell gave to the Department extracts from his report on the Maidens mine, and his plan accompanying the report. To Mr. Warren Emens of the Mining Corporation of Canada, Limited, and to the officials connected therewith, the writer is also much indebted for many details concerning the Frontier and Crompton mines. The generous and kindly manner in which the Keeley Silver Mines, Limited, and the Mining Corporation of Canada, Limited, gave to the Department of Mines all the information which was asked for may be put on record here. Mr. Horace F. Strong furnished the Department with plans of the mine levels of the Wettlaufer, and with a stope section of the Wettlaufer vein; he has also very kindly written an account of the history of the Frontier mine, and a description of the Wettlaufer mine. To Mr. Walter J. D. Penly the writer begs to express his thanks for information regarding the location of certain claims.

Production

To the end of the year 1922, South Lorrain had produced 4,339,984 ounces of silver, contributed by the several properties according to the table on page 192.

Vein Minerals

In South Lorrain, the vein minerals are much the same as at Cobalt. The silver occurs largely in the native state and is, as at Cobalt, the most important mineral. Analyses of four samples of cobalt ore were made by Mr. W. K. McNeill, and his results appear in the table below. It will be noted that three of these samples contain only about one per cent. of sulphur, which proves that if either cobaltite, the sulph-arsenide of cobalt, or mispickel, the sulph-arsenide of iron, is present, it must occur in small quantity. The first three analyses evidently show, therefore, that the cobalt occurs in the form of the mineral smaltite, the diarsenide of cobalt. The high per cent. of iron in sample No. 2 suggests the presence of löllingite, iron diarsenide, which was identified by H. V. Ellsworth at the Kerr Lake mine.

ANALYSES OF COBALT ORE FROM SOUTH LORRAIN

Constituent	Sample No. 1 per cent.	Sample No. 2 per cent.	Sample No. 3 per cent.	Sample No. 4 per cent.
Cobalt.....	14.14	9.46	13.38	11.88
Nickel.....	5.28	0.46	1.50	8.53
Iron.....	3.37	14.42	4.60	6.20
Arsenic.....	70.64	63.06	65.40	64.04
Sulphur.....	1.06	1.48	0.97	4.73
Insoluble.....	0.20	1.42	0.30	0.70

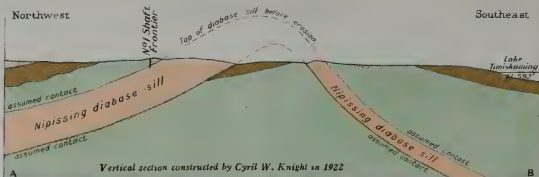
Sample No. 1 from Frontier mine, Wood's vein, fourth level. Sample No. 2 from Keeley mine stock pile. Sample No. 3 from Curry mine dump at inclined shaft. Sample No. 4 from Keeley mine stock pile.

¹Bulletin of the Institution of Mining and Metallurgy, February, 1922.

SILVER PRODUCTION, TROY OUNCES, IN SOUTH LORRAIN TO END OF DECEMBER, 1922

Total oz. to end 1922	Mine	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
1,136,917 ¹	Keeley.....	13,124	11,213	.....	.....	.....	.....	3,534	.....	.....	.....	39,199	4,586	8,253	281,659	775,349
2,564,584	Wetlauffer.....	.....	183,742	199,920	925,017	834,119	248,992	104,665	.....	68,129	.....	.....	.....	.....	.....	.....
42,629	² Pittsburgh-Lorraine Syndicate.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
31,630	Bellellen.....	.....	.....	21,213	8,895	.....	.....	.....	.....	7,629	10,000	25,009	.....	.....	.....	.....
556,185	³ Frontier & Crompton.....	.....	.....	.....	.....	.....	.....	.....	.....	1,522	.....	.....	.....	.....	47,227	508,958
7,989	⁴ Silver Eagle.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7,989	.....	.....	.....	.....
4,339,934	Total.....	13,124	194,955	221,133	933,912	834,119	248,992	108,199	nil	77,280	10,000	72,188	4,586	8,253	328,886	1,284,307

¹Keeley produced 1,655,323 ounces in 1923.²Curry and Wetlauffer.³Frontier and Crompton produced 1,300,323 ounces in 1923.⁴Operated early part of 1918 by John Redington.



SECTION ALONG LINE A—B, SHOWING DOME STRUCTURE OF NIPISSING DIABASE SILL
Horizontal and Vertical Scale, 1 mile to 1 inch.



Veins mapped by the mining companies in 1923;
at depth the veins extend into the Nipissing diabase.
Surface geology mapped by A. G. Burrows in 1908.

GEOLOGICAL MAP OF SOUTH LORRAIN DISTRICT OF TIMISKAMING, ONTARIO

To accompany Ontario Department of Mines Report, Volume XXXI, Part 2, 1922, by Cyril W. Knight
on the Cobalt Silver Area.

Where Veins Occur

The productive veins occur along the top of the Nipissing diabase sill, both in the diabase and in the overlying Keewatin (vertical sections facing pages 193 and 207). In this respect the occurrence is similar to that at the Temiskaming and Beaver mines in Cobalt. The diabase occurs in the form of a great elongated dome, known as the South Lorrain dome, and the productive veins discovered up to the present time have been found on the northwest slope of the dome.

No ore has yet been found in the conglomerate and greywacké of the Cobalt series below the South Lorrain diabase dome. In Cobalt, on the other hand, the rocks below a similar dome, in the Kerr lake-Giroux lake section, have been highly productive, and such mines as the University, Lawson, Crown Reserve, Kerr Lake, and Drummond all occur below the diabase dome in rocks of the Cobalt series.

Pre-Glacial Weathering

In Wood's vein, at the Keeley mine, pre-glacial weathering exists to a depth of at least 480 feet. The weathering has escaped glaciation, and is the only known occurrence of the kind in the entire Cobalt field. The upper part of Wood's vein has been leached and oxidized, and the wall-rock has been changed to red and grey clay for a width of an inch or two to as much as seven or eight feet. This weathering and oxidation is more fully discussed in dealing with the Keeley mine.

The economic significance of pre-glacial weathering in Wood's vein may be important if it is proved that large quantities of secondary silver have been deposited at or near the bottom of the weathered and oxidized zone.

While pre-glacial weathering at the Keeley mine is unique in the Cobalt silver field, it is known, nevertheless, in a few other localities in Ontario. Two notable instances may be cited. At the Helen iron mine, north of Sault Ste. Marie, weathering of a diabase dike and Keewatin schist has taken place to a depth of 540 feet, according to A. L. Parsons. These rocks are altered to grey kaolin.¹ In Hastings county, at the Eldorado copper mine, weathering of iron and copper sulphides has taken place to a depth of 60 to 80 feet, the sulphide having been changed to iron oxide, which yielded a good grade of iron ore. Below the weathered zone primary sulphides were met with. E. L. Fraleck has described this occurrence.² In certain other hematite deposits in southeastern Ontario similar conditions occur, the iron ore passing into sulphide in depth.

Length of Ore-Shoots

The ore-shoots at the Keeley and Frontier mines are shorter than are those at Cobalt. The most consistent high-grade shoot in the Keeley is 74 feet long in vein No. 26; "N" shoot in Wood's vein on the seventh level is 198 feet long. On the 300-ft. level of the Crompton there is a shoot of high-grade 102 feet long in Wood's vein. If we compare the South Lorrain shoots with certain shoots at Cobalt, we shall obtain a just idea of their relative lengths. The stope on the Meyer shoot, with its westward extension on the Trethewey, is about 1,600 feet long. The stope on the O'Brien No. 1 vein on the second level is 900 feet long at the west end of the property. The stope on the No. 3 vein of Kerr Lake is 400 feet long. Other examples might be given.

It may be, of course, that longer shoots will be found in South Lorrain as development and exploration proceed. The writer has not seen the stopes

¹Annual Report, Ont. Bur. Mines, Vol. XXIV, pt. I, 1915, pp. 192-194.

²Ont. Bur. Mines, Vol. XVI, pt. I, 1907, p. 182.

in the Wettlaufer mine. He was, however, given the stope section of the Wettlaufer vein through the kindness of Horace F. Strong; the section shows one of the stopes to have a length of 210 feet on the second level, and 260 feet on the third level.

While the South Lorrain ore-shoots have not yet proved to be as long as those at Cobalt, some of them are very rich. At the Keeley mine, J. Mackintosh Bell reported that in drifting 74 feet along vein No. 26 on the 480-ft. level not less than 250,000 ounces of silver had been mined; no stoping was done in recovering this huge amount. On the 300-ft. level of the Crompton a shoot on Wood's vein 102 feet long and an average height of 35 feet had produced 900,000 ounces of silver to the end of April, 1923.

The "Mother Lode"

The vein-system in the productive part of South Lorrain is an interesting one. The main vein is known as the Wood's vein. It has been named by Dr. J. Mackintosh Bell the "mother lode" of the productive section. It is in a reverse fault, the displacement of which is about 30 feet, and most of the productive veins are probably branches. The relation of the Wettlaufer vein to Wood's vein is not known. The Wettlaufer vein strikes towards Wood's vein at an angle of about 45°, but, in so far as the writer can ascertain, it has not yet been followed to its intersection with the Wood's. According to Horace F. Strong, it "feathers" out about 50 feet southwest of the northeast corner of the Curry, H.R. 105.

Faults¹

The faulting system in South Lorrain is believed to be a complex one. The two main faults are the Lake Timiskaming fault on the east, following the course of the lake, and the Montreal river fault on the west, following the general course of the river. The former strikes north and south, the latter southeastward, so that the two faults join about five miles south of the Keeley mine about at the point where the Montreal river enters Lake Timiskaming.

Between these two major faults it is believed that there are many minor faults, although the only one which has been positively proven to exist is Wood's fault with its small branch faults. The evidence for stating that many other faults exist is the presence of sharply defined valleys. If it is assumed, for the moment, that these valleys are fault valleys, then the number of faults between Lake Timiskaming and the Montreal river is great.

At the north end there is Maidens creek valley striking westward, a few degrees north of west. Running about at right angles to the Maidens creek valley are a number of valleys entering it from the south; one of these begins at the northeast corner of Trout lake, and, striking about north-northeast, passes through the Wettlaufer claim, and then continues to the Maidens valley, a total distance of two and a half miles. This fault may be called the Wettlaufer valley fault. East of this there is probably another fault along the east arm of Loon lake, which continues north-northeast to Maidens valley. The Loon lake fault appears to be exposed to view a few hundred yards south of the lake, where the conglomerate is crushed into a rock similar to the fault breccia found in faults. This breccia is cemented by calcite, dolomite, or other carbonate.

Wood's fault has been proven to strike southward through the Frontier, Crompton, Keeley, and claim No. H.R. 103. It may join the Wettlaufer valley

¹The Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming, by Willet G. Miller, Annual Report, Ont. Bur. Mines, Vol. XIX, 1913, pt. II, pp. 116-121.

fault at some point near the northeast corner of Trout lake. Another fault, entering from the eastward from a little lake on H.R. 98, also seems to join Wood's fault at or near the point that the Wettlaufer valley fault joins it. Another valley enters Trout lake at the northwest corner. Thus there appear to be several faults entering the north end of Trout lake. If these faults, or veins connected with them, contain commercial quantities of silver, they present an interesting problem.

Some of the valleys referred to above are indicated on the map of South Lorrain by A. G. Burrows.

There are several other prominent valleys not mentioned above, notably that about half a mile west of the Frontier mine; and there are also a number of sharp cliffs suggestive of faulting.

A word may be added as to the character of the faults. The Lake Timiskaming fault was first pointed out by Willet G. Miller.¹ Later, G. S. Hume² showed that the fault has a displacement of 800 to 1,000 feet, the east side being the down throw side. The character of the Montreal river fault, whether reverse or normal, is not known; nor is the character of any of the other faults known, except Wood's fault at the Frontier and Keeley, which appears to be a reverse fault with a displacement of about 30 feet.

A word of caution must be added about assuming that all the valleys in South Lorrain represent faults. A valley in Cobalt may be cited which proved to have no fault. This is the valley along which runs the branch line of the Temiskaming and Northern Ontario railway from Cobalt to Kerr lake, opposite the cliff at the "Little Silver" vein on the Nipissing property. The underground workings penetrated below this valley, and no evidence of a fault was found. This may be the case in more than one valley in South Lorrain.

Discovery of Ore Bodies

To those, and there are many, who want to know the likely places in which to explore in South Lorrain, the writer can do no better than to point out how success was achieved during the last two years at the Keeley and Frontier properties. The operators began working at the surface on strong calcite veins, an inch to a foot or more in diameter; these veins contained small shoots of cobalt ore; the silver was negligible. The veins outcropped in Keewatin rocks three to four hundred feet above the top of the Nipissing diabase sill. The operators sank on the veins to the contact of the Nipissing diabase and Keewatin basalt. Exploration of the veins along and near the contact revealed the rich ore-shoots which have brought the camp into such prominence. Another factor, however, besides the diabase contact played its part at the Keeley mine. J. Mackintosh Bell believed that, at or near the bottom of the pre-glacial weathered zone in Wood's vein, he would find rich masses of secondary silver ore which had been leached out of the top part of the vein. While the bottom of the weathered zone has not yet been reached at a depth of 480 feet, there is evidence nevertheless that the workings are approaching it. At any rate, most of the high-grade ore in the mine has been encountered at this depth.

Those seeking new ore bodies in South Lorrain should also keep in mind the conglomerate and greywacké of the Cobalt series below the South Lorrain dome, in the vicinity of Loon and Oxbow lakes. Up to the present time no calcite veins of importance are known in these rocks under the dome. Should

¹Annual Report, Ont. Bur. Mines, Vol. XIX, pt. II, 1913.

²The Ordovician Rocks of Lake Timiskaming, Geol. Surv. Can., Museum Bulletin No. 17; Am. Jour. Sci., 4th ser., Vol. 50, 1920, pp. 293-309.

strong calcite veins, with smaltite, be discovered by trenching or diamond drilling such veins might be explored along the base of the Cobalt series. In Cobalt much of the silver ore occurs along the base of that series; similar conditions may exist in South Lorrain under the diabase dome.

Maps and Plans

In the pocket at the back of the report will be found a detailed surface geological map of the productive area of South Lorrain, on a scale of 400 feet to an inch. The map shows the kinds of rocks, the location of the veins, contour lines, buildings, and so on. This map was prepared by the Mining Corporation of Canada, Limited, in co-operation with the Keeley Silver Mines, Limited. The work is wholly theirs, and the geology is based on A. G. Burrows' map, scale one mile to an inch, published in 1909 by the Ontario Department of Mines. The writer herewith expresses the thanks of the Ontario Department of Mines for the generous manner in which the companies concerned handed over the entire map for publication in this report. The map was made by the companies on a scale of 100 feet to an inch; the Department has published it on a scale of 400 feet to an inch.

In the pocket will also be found a sheet showing the plans of all the levels of the Keeley and Frontier mines. The geology, veins, faults, and so forth, are shown.

General Geology

The following classification of the rocks in South Lorrain is largely based on that given in the report of A. G. Burrows,¹ to which the reader is referred. The rocks have been fully described in Burrows' report, and it is not necessary to add much, beyond referring to the presence of lamprophyre dikes of Haileyburian age which have since been found. The Nipissing diabase has, since the early work, been proved to occur in the form of a sill with a great dome-like structure. In view of the importance of this dome structure, the writer has described it in somewhat great detail in following pages.

TABLE SHOWING ROCK CLASSIFICATION OF SOUTH LORRAIN

PRE-CAMBRIAN	KEEWENAWAN	{ Silver veins. Nipissing diabase sill.
	INTRUSIVE CONTACT	
	ANIMIKEAN (Cobalt Series)	{ Lorrain quartzite, arkose and conglomerate. Conglomerate, greywacké, slate-like greywacké, quartzite.
	GREAT UNCONFORMITY	
	ALGOMAN	Granite and syenite, feldspar-porphphyry.
	INTRUSIVE CONTACT	
	HAILEYBURIAN	Lamprophyre dikes,
	KEEWATIN	Basalt and similar basic lavas, much altered in places.

The South Lorrain Diabase Dome

The Nipissing diabase in South Lorrain occurs, as in Cobalt, in the form of an irregular sill, hundreds of feet thick. Its exact thickness in South Lorrain is not known, and will not be until the diamond drill or shafts have penetrated it.

The sill has the shape of a great elongated dome, the longer axis of which strikes northeastward. The dome structure is illustrated in the drawing facing

¹Annual Report, Ont. Bur. Mines, Vol. XIX, pt. II, 1913, pp. 134-144.

page 193, which shows a vertical section at right angles to the longer axis. A study of this vertical section, and the plan accompanying it, will explain the structure much better than a page or two of text.

It is believed that the dome-like structure of the diabase sill was not caused by folding, but that the diabase was intruded in that form during its molten state. Of course there may have been a little subsequent folding, but the gentle dips of the slate-like greywacké and conglomerate of the Cobalt series show that there has been comparatively little disturbance.

The top of this diabase dome, during a great period of time, has been slowly eroded and worn down until, finally, all that now remains of the dome is the lower part with its encircling arms dipping away from the centre.

Contacts of the bottom of the diabase sill with the underlying rocks around the inside of the dome are exposed in a score of places, showing the diabase dipping away from the centre at angles varying from 5° or 10° to as high as 65° . Similarly, the top of the diabase sill around the outside of the dome is exposed in many places, and the top of the sill may be seen plunging under the older rocks at angles of 15° to as high as 80° or 90° . The almost vertical dips along the top of the sill were noted in the valley of Maidens creek along the north part of the dome.

Details of the South Lorrain Diabase Dome

As the dome-like structure of the Nipissing diabase sill is one of the most important structures in South Lorrain, it is described rather fully.

The evidence proving that the diabase forms a dome may readily be obtained by following the contacts around the inside and outside of the dome. The contacts around the inside of the dome show the bottom of the diabase sill; while the contacts around the outside of the dome show the top of the diabase sill. The contacts which were found may now be described in detail, beginning with the outside of the dome on the shores of Lake Timiskaming, at Maidens creek, half a mile north of the government wharf.

The Outside of the Diabase Dome (Top of the Sill)

The actual contact of the top of the dome is heavily covered with drift for a mile and a half westward from the shore of Lake Timiskaming. The contact appears to follow the south side of Maidens creek valley. The first contact observed was found on or near claims Nos. R.L. 461 and H.S. 11, where it is excellently exposed, particularly at one place. At this place a hill rises about 25 feet high, and the contact goes up one side and down the other, and is seen to be vertical. The actual contact is exposed for about 60 feet. Elsewhere on the two claims mentioned above, there are half a dozen contacts exposed, but the dip of the diabase is obscure and could not be positively determined; at one place, indeed, the diabase seemed to be resting on top of the Keewatin. This may, however, be a local irregularity.

Half a mile northwest the contact is again excellently exposed in a valley, through which the main road runs, on claim No. B.C. 105. The valley cuts across the contact at right angles. Standing at the bottom of the valley and looking southeast up the hill, the contact of the diabase is seen to extend up the hill. It is vertical. Similarly, standing in the valley and looking northwest, the contact is seen to extend up the other side of the valley and to be also vertical. The rock with which the diabase is in contact is a pink quartzite. The colour of the quartzite makes a sharp contrast with the dark colour of the diabase. The contact is vertical for at least 50 to 75 feet.

The vertical contacts described in the preceding paragraphs are along the north side of the diabase dome, where the only known vertical contacts have been found. There is no way of determining to what depth this vertical contact extends except by diamond-drilling or shaft-sinking. A knowledge of the dip of the diabase at the Maidens claim, H.R. 69, is of practical importance on account of the veins which occur there.

The northwest end of the diabase dome terminates in a spur about 300 yards wide. At the north end of this spur, a shaft has been sunk in the diabase near the quartzite. The shaft dips about 55° or 60° to the southwest. The rock on the dump is diabase. There are on the dump pieces of a pink calcite vein about three or four inches wide carrying a little cobalt bloom. The latter mineral may be seen in place in a joint in the rock about six feet southeast of the shaft. Evidently the inclined shaft was sunk on this joint. West of here about 450 feet another shaft has been sunk, apparently at the contact between the diabase and quartzite. This shaft is in a valley, the contact here following the valley as it curves around to the west, southwest, and south. The rock on the dump from this shaft is coarse and fine grained diabase.

From the north end of the spur the contact runs about due south for nearly four miles to the south end of Trout lake. This part of the contact, up to the present time, is the most important part in the whole South Lorrain area because the productive properties, Wettlaufer, Keeley, and Frontier, occur here.



Fig. 46—Mr. J. M. Wood



Fig. 46a—Mr. R. J. Jowsey

These partners were pioneers in South Lorrain and joint discoverers of the Keeley mine. The "Wood's" vein was named after Mr. Wood. The Keeley mine was named after Mr. Charles Keeley who was associated with Jowsey and Wood.

Commencing at the north end of this important part of the sill the contacts may be described in detail.

About 300 yards south of the north end, fine-grained diabase occurs along the side of a hill. The slope of the hill appears to indicate the dip of the diabase, namely, about 30° or 35° to the westward. The diabase here is dipping under conglomerate and greywacké of the Cobalt series.

The first satisfactory place to examine the contact along this four-mile stretch is about three-quarters of a mile south of the north end of the dome, on claim No. R.L. 467, known as the Alice Lorrain. A shaft has been sunk on this claim. About 125 yards southwest of the shaft, the contact is excellently exposed for about 40 feet; the contact dips steeply westward under the Keewatin.

South of here three claims, on the Lorrain Consolidated property, No. H.R. 24, the contact is excellently exposed along the side of a hill. It dips to the westward at 15° to 22° , but is much steeper in places. South of this exposure the contact goes below swampy or low ground, and is not exposed until the Keeley property is reached, where at the roadside, about 75 yards from the old Keeley shaft, it dips westward. Between this last-mentioned exposure and the Wettlaufer mine, there are several excellent exposures of the contact, all dipping westward under the Keewatin.

At the Frontier, the diabase dips about 25° to the westward in the vicinity of No. 1 shaft; this dip is shown by the mine workings.

At the Keeley, to the south of the Frontier, the dip of the diabase is about 34° westward; this dip is also shown by the Keeley workings. The drawings facing pages 207 and 219 show the dip of the diabase contact at the Keeley and Frontier.

The Wettlaufer mine was flooded at the time of examination of the area in October, 1922, so that it could not be inspected. But it was learned from those who had examined this mine that the diabase dips below the Keewatin at steep angles. On the surface the contact is exposed at more than one place, and is particularly well shown near the east side of the valley, where the diabase dips under the Keewatin at an angle of about 15° . From this exposure southward to Trout lake the contact is covered with soil.

At the south end of Trout lake, on the east side, the contact between the conglomerate of the Cobalt series and the top of the Nipissing diabase is well exposed. At two places the contact dips 45° to the westward. Southeastward from here about two claims, on No. H.S. 497, the diabase contact is exposed on the side of a bare hill and dips 44° to the south. This contact is located at about the most southward part of the Nipissing diabase dome.

Northeast of here, on the next claim, No. H.S. 500, the contact is well exposed in three places, dipping from 36° to 51° to the southeast. Two of these contacts are on the side of a hill. It may be noted here that many of the contacts observed in South Lorrain are on the side of valleys, as frequently as they are in the bottom of valleys. On H.S. 500 little acid dikes from one-half to two inches wide intersect the diabase; these dikes were noted elsewhere in the area.

Northeast of the last-mentioned contacts about a mile, the contact is exposed on H.R. 113, but the dip could not be ascertained.

Two claims to the northeast, on H.R. 54, at the northwest corner, the contact is exposed in two places dipping 41° and 55° , respectively, to the southeast. The Keewatin basalt is here altered to a banded, slightly schistose rock; the diabase has cut about at right angles across the banding, making the contact sharp and clear-cut.

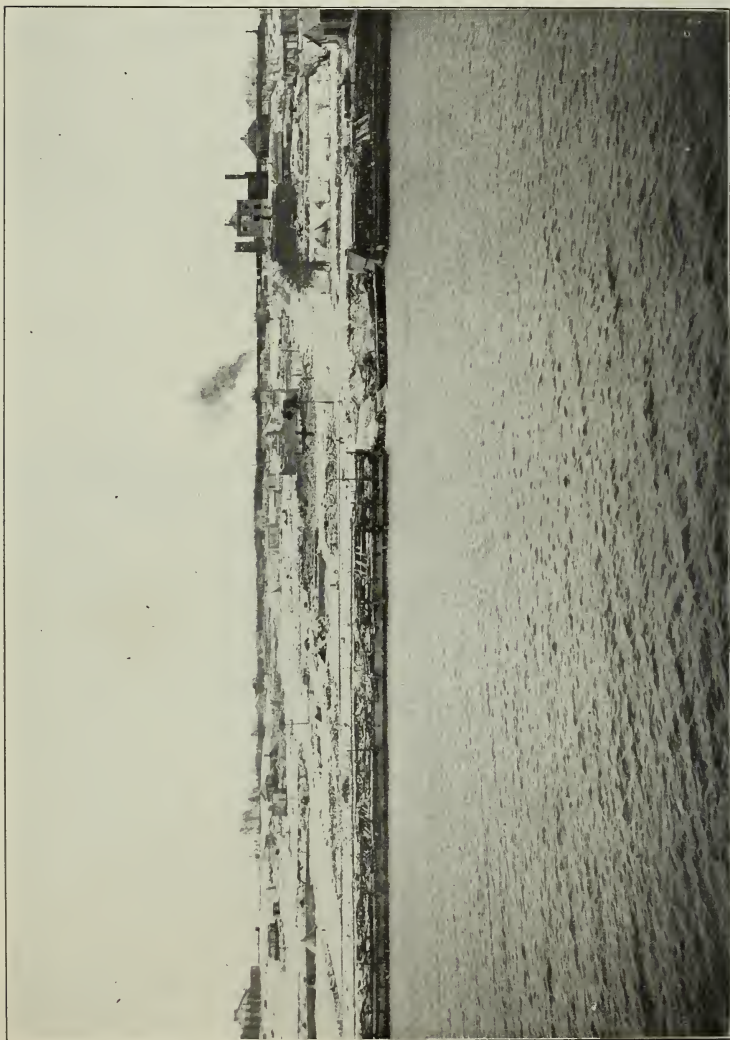


Fig. 47—Haileybury, five miles north of Cobalt, Oct. 27th, 1922, after the great fire of Oct. 4th, 1922.
Lake Timiskaming in the foreground.

Northeast of the last exposure the contact is again exposed on H.R. 27 at the northeast corner. Judging by the jointing in the diabase, the contact dips 25° to the southeast.

From this point eastward to the shore of Lake Timiskaming, the contact is drift-covered, except at the hill on the side of the lake. Here, near the north end of claim No. H.S. 308, the contact is exposed in two places about 40 feet apart, one exposure being just north of the boundary and the other just south of it.

The contact dips 25° to 30° to the southeastward. The Keewatin basalt is altered to a banded rock with streaks of epidote paralleling the banding; the diabase cuts about at right angles across the banded basalt, and the contact is sharply defined in consequence. At the foot of the hill the coarse-grained Nipissing diabase is exposed, and a shaft has been sunk in it.

In the preceding paragraphs we have followed almost completely around the outside of the Nipissing diabase dome. The east part of the dome is partly covered by the water of Lake Timiskaming, but outcrops on the Quebec side of the lake along the shore. According to the geological map-sheet No. 1066, of the Geological Survey of Canada, the diabase contact near the shore is drift-covered.

The contact along the inside of the diabase dome may now be followed, commencing at the shore of Lake Timiskaming at the south end of claim No. H.R. 61.

The Inside of the Diabase Dome (Bottom of the Sill)

The bottom of the Nipissing diabase is well exposed a little over half a mile west of Lake Timiskaming on or near claim No. H.R. 30. Forest fires have destroyed the trees, and lines are difficult to find. At the foot of a low cliff the diabase contact is exposed in two places, resting on finely bedded slate-like greywacké of the Cobalt series. The contact follows the bedding; contact and bedding dip 9° to the northwest at one point and, at another 200 feet north, 13° to the northwestward. The jointing in the diabase is well defined along the contact, the most prominent jointing being at right angles to the contact.

From claim H.R. 30 westward to the northwest shore on Loon lake, a distance of a mile, the contact is either heavily drift-covered or hidden under the water of Loon lake.

Southward from the northwest corner of Loon lake for half a mile, the contact of the bottom of the diabase sill is exposed in half a dozen places. Prospectors have trenched it here and there. The contact has a semicircular outline along this part, so that the dips strike from southwest, to west, to northwest, at angles of 10° to 35° . This semicircular outline of the contact is due to a local arching of the bottom of the sill, the arch striking apparently about northwestward along the west arm of Loon lake. At the top of the arch the diabase is resting on pink arkose and quartzite, while at the bottom of the arch, on the southwest side, the diabase rests on finely bedded slate-like greywacké. Where it lies on the slate-like greywacké it follows the bedding for a distance, then it leaves the bedding and rips upwards across the bedding, resting on the sediments at a higher and higher horizon, until it finally rests on the pink arkose and greywacké at the top. The succession of the sediments of the Cobalt series in this place is as follows, the older rocks being shown at the bottom of the column:

Arkose and quartzite.

Greywacké and slate-like greywacké.

Coarse boulder conglomerate.

The bedding of the slate-like greywacké dips at 10° to 14° to the northwest. The greywacké and slate-like greywacké have a thickness of 50 to 60 feet, and the total thickness of the whole section is from 150 to 200 feet. The coarse boulder conglomerate is at the bottom of the section; its thickness is not known. The arkose and quartzite are similar to the Lorrain arkose and quartzite, while the greywacké, slate-like greywacké, and conglomerate are typical of the Cobalt series. The sediments are all conformable.

In places faulting has occurred parallel to the contact in the area southwest of Loon lake described in the two preceding paragraphs. The faulting is indicated by the presence of a fault breccia 15 inches or less in width; the direction and displacement of the faulting were not determined.

Southwest of the area described in preceding paragraphs the diabase contact is covered for three-quarters of a mile, when it is again well exposed on the south shore of a small lake on claim H.R. 98. The contact is exposed for 50 feet dipping at 40° and more to the westward.

About 250 yards south of the little lake the diabase contact is again exposed for about 40 feet; judging from the joint planes in the diabase, the bottom of the diabase sill here dips southwestward 30° to 40° . The slate-like greywacké nearby dips at 10° to the southwest.

South of the exposure referred to in the preceding paragraph another contact is exposed, but the direction of the dip is obscure. The slate-like greywacké dips 10° under the diabase.

About 200 yards north of the west arm of Oxbow lake, another contact is exposed for 50 feet. The dip is obscured by a fusion between the diabase and the sediments; the jointing in the diabase dips 38° westward.

Oxbow lake constitutes the south end of the inside of the Nipissing diabase dome, and the contact of the bottom of the sill follows the bed of the lake in a rough semicircle, the contact being covered by water for more than a mile.

The southeast side of the dome dips at steeper angles than the northwest side, and the diabase sill along the southeast side appears to be thinner than elsewhere.

For a mile northeast of the east arm of Oxbow lake, the bottom of the diabase sill is drift-covered. Then, 200 feet southwest from the northeast corner of claim H.R. 34, the contact has been exposed in a trench. Here the diabase is resting on altered Keewatin basalt which has a banded structure. The contact dips at 62° to the southeast.

From the last-mentioned exposure northeast for a mile and a half to Lake Timiskaming, the contact is drift-covered, and it then passes below the waters of the lake.

DESCRIPTION OF PROPERTIES

Keeley

The Keeley Silver Mines, Limited, has a capital of 2,000,000 shares having a par value of one dollar a share. All the shares have been issued. The company bought the original Keeley claim, H.R. 19, and the claim immediately to the west, H.R. 21, known as the Beaver Lake claim.

The property was examined in the fall of 1921 and 1922, and brief visits were also paid during the latter part of January and early in May, 1923.

The first discovery was made by J. M. Wood and R. J. Jowsey on the original Keeley claim, H.R. 19, in the fall of 1907, and the first shipment of ore from the discovery was made by the owners of the claim, Charles Keeley, R. J. Jowsey,

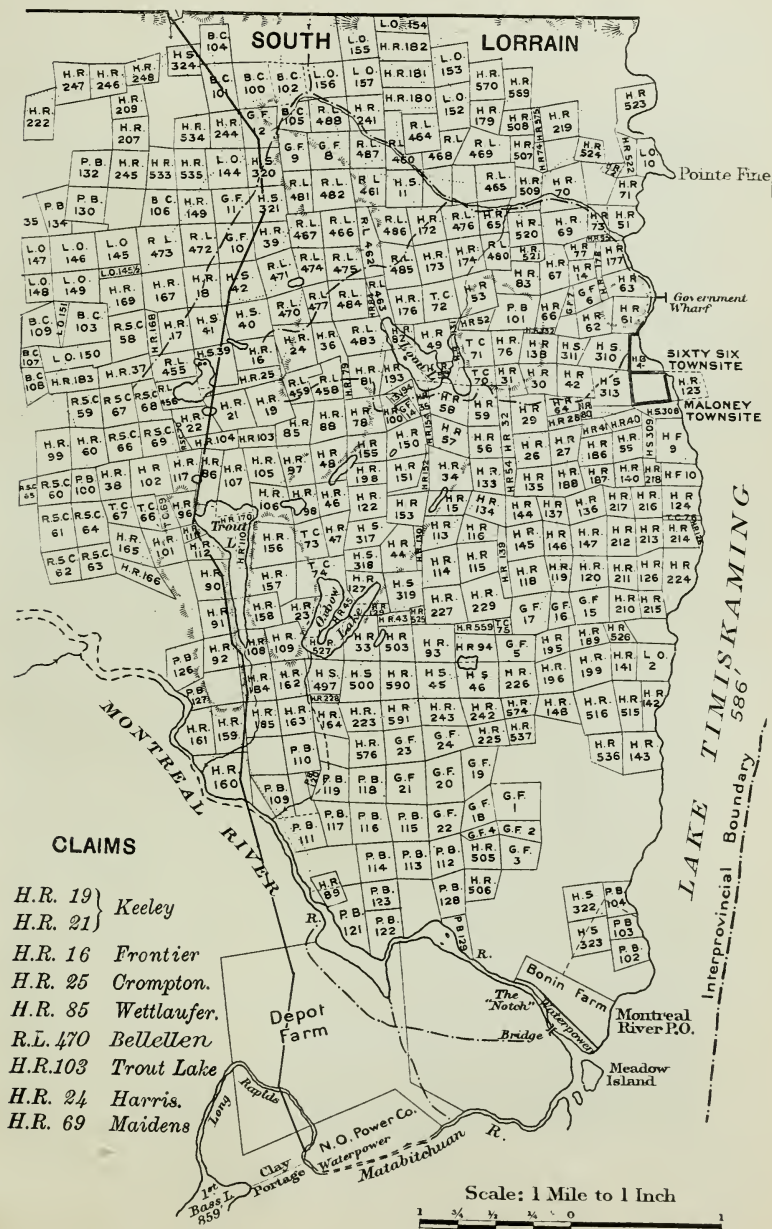


Fig. 48—Plan showing claims in South Lorrain.

and J. M. Wood, in the spring of 1908, and was received by the Deloro Mining and Reduction Company, Limited, Deloro, Ont., on the twenty-second of June of that year. The shipment consisted of twelve tons, dry weight, assaying 1,061 ounces of silver per ton. The value of the shipment was \$6,068.52, of which amount \$170.32 was credited to the cobalt and arsenic content. In the latter part of March, 1908, Mr. James Bartlett and the writer examined the open pit from which this shipment was made.¹ The pit was about 40 feet long and 14 feet deep, and the vein had a width of two to six inches showing some pure smaltite and wire silver.

The following account of the discovery of the Keeley mine has been kindly furnished by R. J. Jowsey:—

The find on the Keeley was made in the fall of 1907. J. M. Wood had been digging while I had gone to Haileybury for some provisions. I went to Haileybury on the last trip of the boat, and the lake froze, so I had to pack the supplies down on my back. When I returned Wood had found a chunk of smaltite, and had it in the camp when I arrived. I went out and helped him dig that evening, and next day, about three o'clock, he uncovered the vein when I was a little farther ahead in the trench. We left it on the window sill a couple of days, as it looked to be just smaltite. On Sunday we were looking at it when it had dried out, and noticed all those fine hairs in it. We were not sure of its value, so we had it assayed. If I remember right it was around 11,000 ounces of silver per ton.

Messrs Keeley, Jowsey, and Wood then sold the property to interests connected with the now defunct Farmers Bank. The bank was only interested in the property on account of having made advances on a million dollars worth of bonds issued by Keeley Mine, Limited; and the bank was never owner of the mine. Keeley, Jowsey, and Wood received \$300,000 for the property. The total amount advanced by the bank, including the purchase price, wages, cost of plant, etc., was much greater than the above mentioned sum.

The property, under the name of Keeley Mine, Limited, was worked by interests associated with the bank until 1911, and about 24,337 ounces of silver were produced, mainly from the original discovery, No. 1 shaft. Wood's vein was not worked during this period in the history of the mine.

The affairs of the Farmers Bank then became involved, and the bank failed. The liquidators of the bank found themselves in possession of the Keeley mine, H.R. 19, but they did not allow the operating company, Keeley Mine, Limited, to fail. It was kept in good standing.

In 1913, J. Mackintosh Bell acquired an option on the property for the Associated Gold Mines of Western Australia, Limited. An option had been granted on the 26th March, 1913, by Keeley Mine, Limited, and the Farmers Bank to one, E. G. Aman, which option was assigned to the Associated Gold Mines of Western Australia, Limited, on the 12th June, 1913. The Associated Gold Mines of Western Australia, Limited, obtained several renewals of that option, and on the 23rd April, 1918, they obtained the last option. These were given by the Keeley Mine, Limited, and the Farmers Bank. The final payment on the property was made on August 1st, 1919; the total price paid was \$110,000. Upon the Associated Gold Mines of Western Australia, Limited, making the final payment they received a transfer from Keeley Mine, Limited, and the Farmers Bank of the property, and they also received the majority of the stock in Keeley Mine, Limited, and the bond issue of a million dollars made by Keeley Mine, Limited, which was held by the Farmers Bank. Eventually these bonds were burned by J. Mackintosh Bell and the solicitor of the present company, W. H. Stafford. The writer is greatly indebted to these two gentlemen for much of the information regarding the history of the property.

¹Annual Report, Ont. Bur. Mines, 1907, Vol. XVI, pt. II, p. 147.

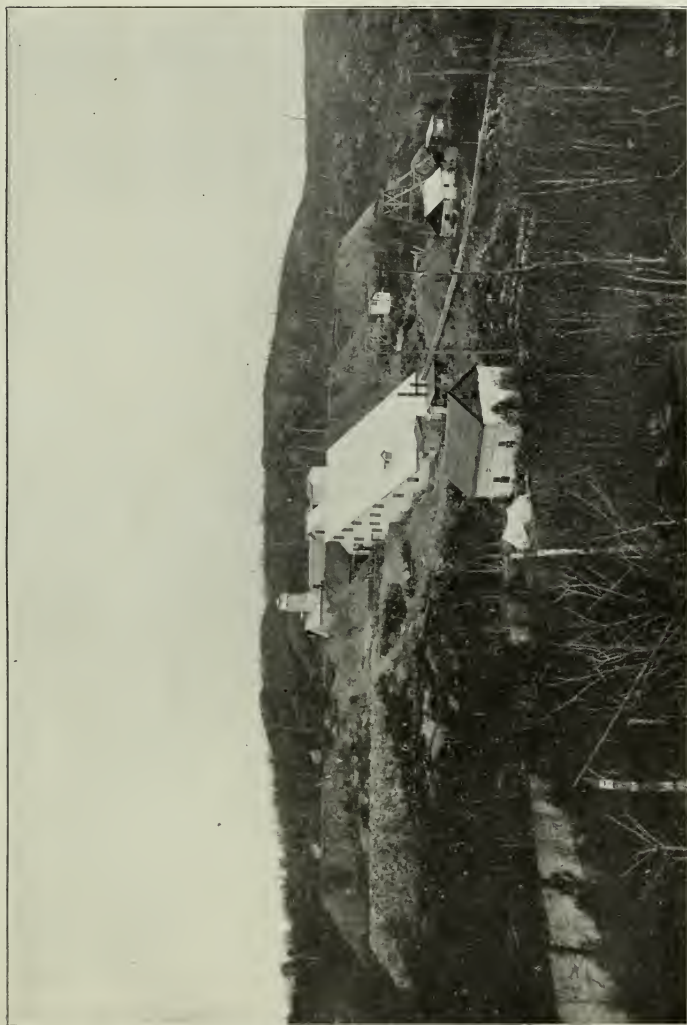


Fig. 49—Keeley mine and mill, October, 1922.

The Associated Gold Mines of Western Australia, Limited, did not operate the original discovery at the Keeley mine, No. 1 shaft, nor have these old workings been connected with the main, present-day workings on Wood's and other veins at No. 3 shaft.

Between the years 1913 and 1919, work at the property was retarded and carried on intermittently on account of the Great War which lasted from 1914 to 1918. In 1914, the mine was worked with a force of 85 men, but, following the outbreak of war, the force was reduced in August from 85 to 20 men, and in September to 6 men, who were sinking by hand in No. 2 shaft. The mine ceased operations about the middle of October, 1914.

In 1915, the mine was worked from May to October 1st. In 1918, a shipment of ore, in stock from previous operations, was made; and the property was in operation between July and September. In 1919, work was carried on during the summer months with a force of 15 men.

Subsequent operations have been highly successful, and the mine has been operated without cessation up to the time this report went to press.

On account of the fact that Wood's vein, the "mother lode" of the productive section, was first discovered on the Beaver Lake claim, a few words may be added about its history. The claim, as already noted, is now owned by the Keeley Silver Mines, Limited, and is contiguous to the original Keeley, H.R. 19, on the west.

Wood's vein was discovered in 1908 by J. M. Wood on the Beaver Lake claim, H.R. 21. The southern two-thirds of the vein outcrops on the Beaver Lake claim; the northern third of the vein passes into the original Keeley claim. In 1908 and 1909, Jowsey and Wood sank a shaft on Wood's vein, on the Beaver Lake claim, near the west boundary of the Keeley. The shaft was sunk to a depth of 110 feet, and on the 75-ft. level a drift 75 feet long was run. Had Jowsey and Wood drifted a short distance farther north they would have encountered a very rich ore-shoot known as D 3 (Fig. facing page 216), although only a small part of the shoot is in the Beaver Lake claim, most of it passing into the Keeley. But had Jowsey and Wood found this shoot, the Keeley would undoubtedly have heard about it, and would have worked that part of the shoot which is in the Keeley and which constitutes the largest part. The shoot has proved to be an important producer, and, if it had been discovered in those days, the discovery certainly would have led to an exploration of Wood's vein. Perhaps the rich ore-shoots four or five hundred feet below the surface might have been encountered by Farmers Bank interests, and the bank might have thus been saved from failure. But these are idle speculations. It remained the good fortune of the present company to discover at depth the fabulously rich silver ore of Wood's vein. Such are the vicissitudes, such the tragedy and romance of mining!

The credit for the discovery of Wood's vein must be given to Wood; and although this pioneer and his partners Jowsey and Keeley did not find any ore, they did find flakes of native silver in the vein.

Some of the early history of the Beaver Lake claim is recorded by the inspectors of mines for Ontario and by A. G. Burrows, and their remarks are quoted below.

In 1908, the inspector of mines reported that the following work was done on Beaver Lake claim:—

The claims H.R. 21 and H.R. 22 are owned by the original owners of the Keeley mine, Messrs Keeley, Jowsey, and Wood, and lie immediately to the west of it. Considerable trenching was done on the two claims during 1908, and veins carrying silver discovered. A shaft has been sunk on it 25 feet, and sinking was to be continued. This vein [Wood's] had a strike of about north and south, and was only a short distance from the west boundary of the Keeley claim.¹

¹Annual Report, Ont. Bur. Mines, Vol. XVIII, pt. I, 1909, p. 125.

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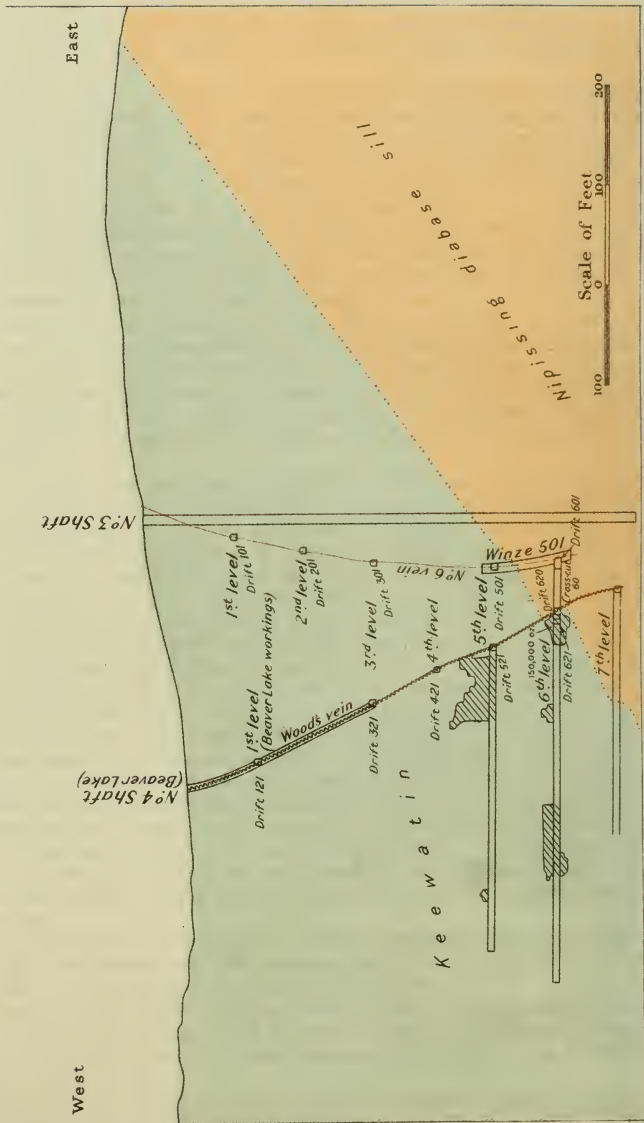
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(Furnished by the Keeley Silver Mines Ltd.)

VERTICAL SECTION ALONG VEIN 16 AND THROUGH NO. 3 SHAFT, KEELEY MINE

SOUTH LORRAIN, DISTRICT OF TIMISKAMING, ONTARIO

To accompany Ontario Department of Mines Report, Volume XXXI, Part 2, 1922, by Cyril W. Knight on the Cobalt Silver Area.

In 1909 the work reported on the Beaver Lake claim, H.R. 21, by the inspector of mines, was as follows:—

Messrs Jowsey and Wood have been operating on claims H.R. 21 and H.R. 22, lying west of and adjoining the Keeley mine. A shaft has been sunk to a depth of 110 feet, and, on the 75-ft. level, 75 feet of drifting done.¹

A. G. Burrows, in 1913, has the following remark to make concerning the Beaver Lake claim, H.R. 21:—

On H.R. 21 there are several calcite veins, and one of these has shown on development native silver. This vein is near the east side line and strikes about north-northeast. A shaft has been sunk to a depth of 110 feet, and on the 75-ft. level, 75 feet of drifting has been done. The gangue is calcite, which has a very fine crypto-crystalline texture, associated in bands with quartz and decomposed material. Leaf silver, in small flakes, has been found in the vein, associated with smaltite, copper pyrites, and native bismuth. Minute crystals of chloanthite are scattered through the gangue.²

Veins and Rock Structures

The structure of the rocks and the relation of the veins to the rocks are shown in the drawing facing page 207. The veins occur at the top of the Nipissing diabase sill, both in the sill and in the overlying Keewatin. The top of the sill at No. 3 shaft dips westward at an angle of 34°. Most of the ore has been found along this contact at a depth of 400 to 500 feet below the surface. An important shoot of ore was, however, met with only 55 feet below the surface; this shoot is known as D 3 in Wood's vein. There are also other ore-shoots, 200 or 300 feet above the contact, which are on the whole much lower in grade than those along the contact.

There are five main veins on the Keeley which are worked from the main or No. 3 shaft. The veins at No. 1 shaft, the original discovery, are described elsewhere in this report; they have not been worked by the present company.

The five veins referred to are Wood's, and Nos. 26, 16, 6, and 20. The most important vein is Wood's. The others are branches of this vein. There are several other minor veins.

Wood's, Nos. 26, 16, and 6 are fault veins with displacements up to 30 feet. The writer has not had an opportunity of examining No. 20 vein. The displacement along vein No. 26 is not yet known.

Wood's vein occurs in a reverse fault, having an apparent displacement along the dip of about 30 feet, as nearly as could be ascertained in the present state of development of the mine workings. The horizontal displacement is not known, but the presence of more or less horizontal scratches on the walls of the fault show that some horizontal movement took place. The vein strikes about north and south, and dips eastward at an angle of 65°. The breccia of the fault is not wide, perhaps averaging one to six inches, in places being almost entirely absent. The gouge, too, is narrow, showing only small fractions of an inch in width; in the weathered and oxidized zone the gouge is an inch wide. In places the walls of the fault are schistose. The vein in Wood's fault is, in places, exactly in the fault; that is to say, it abuts against the gouge. In other places the vein is in the hanging wall a foot or two above the gouge; and, in other places, it is in the footwall a foot or two below the gouge. In the same face of the drift, from time to time, veins have been noted in the hanging wall, in the footwall, and in the gouge. In places several irregular veins occur across a width of four or five feet. The breccia of the fault is in places cemented together by vein material, and the veins thus form an irregular network intersecting the fault breccia.

¹Annual Report, Ont. Pur. Mines, Vol. XIX, pt. I, 1910, p. 114.

²“ “ “ “ “ Vol. XIX, pt. II, 1913, p. 143.

It is difficult to say what is the average width of Wood's vein. In places vein matter is almost absent, while in one place on the fourth level the vein has a width of three to four feet. It may average between three inches and a foot in width.

Some replacement of the wall-rock by vein matter has taken place.

Pre-Glacial Weathering

An interesting and unique condition occurs on the south part of the Wood's vein. Pre-glacial weathering has been preserved in this part of the vein (Fig. facing page 216). It has reached a depth of at least 480 feet below the surface. In no other mine in the entire Cobalt area has pre-glacial weathering been preserved, although, as stated elsewhere in this report, good examples are found in connection with ore bodies in other parts of Ontario. There is no absolute proof that the weathering is pre-glacial. It is simply assumed that sufficient time has not elapsed since the retreat of the glaciers to have allowed such deep weathering to form. J. Mackintosh Bell was the first geologist to observe these conditions and he has given the first description of them.¹ For convenience, the term "weathering" may include disintegration, solution, leaching, oxidation, and hydration. The mine workings have penetrated this weathered zone on the third, fourth, fifth, sixth, and seventh levels. The third level penetrated the weathered zone for 600 feet; no indication was there noted that it was becoming less intense at the south end of the drift. The weathering has altered the country rock to a more or less soft clay. In places the clay has a reddish-brown and yellow colour. Elsewhere it has a pale greenish-grey colour. Towards the bottom of the weathered zone, the pale greenish-grey clay is more common than the red clay. That is to say, the red variety of oxidation occurs, for the most part, at and near the surface, and the grey variety occurs, for the most part, at depth.

Judging from chemical analyses and tests made by W. K. McNeill, the red colour of the clay is due to ferric oxide, while the pale greenish-grey colour is due to ferrous oxide.

In places there is a sharp line of demarcation between the red clay and the grey clay; in other places there is a more or less gradual transition between the two. In the case of the sharp line of demarcation, the fault sometimes separates the grey clay from the red.

The alteration of the country rock to clay was noted in one place across a width of six or seven feet. It is, on the average, much less than that.

The zone of contact, which is a very gradual one, between the weathered rock on the south and fresh solid rock on the north, is about vertical.

The writer has been asked the question, whether the weathered zone will extend south to Trout lake, a distance of about half a mile, and whether it will follow along the bottom of Trout lake, a distance of a mile farther south. This can be answered only by exploration of the ground. It is very doubtful, however, if the weathering will persist unless the Wood's or some other fault extends south to Trout lake. The reason that pre-glacial weathering has been preserved is that it followed down Wood's fault along a narrow zone on each side of the fault. Glaciation was not intense enough to remove the solid fresh rock on each side of the fault. Hence the preservation of the weathered zone in Wood's fault.

J. Mackintosh Bell forwarded two samples of ore from the weathered zone of Wood's vein to Ledoux and Company, New York. One of these samples

¹"The Occurrence of Silver Ores in South Lorrain, Ont., Canada," Bulletin, Inst. Min. and Met., February, 1922.

was the red, ferric variety of weathered ore, and the other was the ferrous variety. Ledoux and Company found that the ferrous ore contained a large proportion of metallics, which were principally silver. The sample of ferric ore contained, on the other hand, no metallics.

Ledoux and Company's letter, addressed to the Keeley Silver Mines, Limited, regarding these samples, is given below:—

Practically complete analyses have been made on two samples of ore referred to in your letter of December 28, 1922.

The first sample, designated as "ferrous ore," contained a large proportion of metallics which were principally silver. On fine grinding we obtained: Pulp, 91.68 per cent.; Metallics, 8.32 per cent. Since in the ordinary practice of treating this ore, the metallics would be separated in the preliminary stages by ball-mill crushing or otherwise, particular attention has been paid to analysis of the fine pulp, and only the principal elements in the metallics have been determined. Our analysis of the ferrous ore is as follows:—

	Pulp per cent	Metallics per cent.	Composite per cent.
Silica (SiO ₂).....	43.24	.....	39.6
Iron (Fe).....	10.33	4.69	9.9
Alumina (Al ₂ O ₃).....	12.06	.....	11.1
Lime (CaO).....	2.42	.....	2.2
Magnesia (MgO).....	6.92	.....	6.3
Manganese Oxide (MnO).....	0.68	.....	0.6
Arsenic (As).....	10.36	10.42	10.4
Antimony (Sb).....	0.53	.....	0.5
Copper.....	0.07	.....	0.1
Cobalt.....	0.33	.....	0.3
Silver.....	4.59	73.36	10.3
Sulphur.....	0.26	.....	0.2
Phosphoric Anhydride (P ₂ O ₅).....	0.30	.....	0.3
Gold.....	trace	0.06	.....
Bismuth.....	None		
Lead.....			
Zinc.....			
Nickel.....			
Selenium.....			
Tellurium.....			

Silver.....3008.5 oz. per ton of 2,000 lbs.
Gold..... 0.88 oz. per ton " " "

It will be noticed that the elements determined in the pulp account for only 92 per cent. The balance is made up of oxygen combined with some of the iron and with other elements, combined with water as an essential part of the gangue and the alkali metals, potash and soda. The calculation of the composite is on the assumption that the metallics do not contain the constituents of the gangue matter, but of course some gangue constituents are included in the metallics. The metallics consist essentially of native silver, silver arsenides and iron.

The ferric ore developed no metallics on crushing and grinding. Our analysis shows:—

	Per cent.
Manganese Oxide (MnO).....	1.33
Silica (SiO ₂).....	45.46
Iron (Fe)..... (Fe ₂ O ₃ 15.24)	10.67
Alumina (Al ₂ O ₃).....	19.92
Lime (CaO).....	1.69
Magnesia (MgO).....	3.92
Arsenic (As).....	0.38
Antimony (Sb).....	Trace
Copper (Cu).....	0.06
Cobalt (Co).....	0.28
Silver (Ag)..... (3.00 oz. per ton of 2,000 lb.)	0.01
Sulphur (S).....	0.10
Phosphoric Anhydride (P ₂ O ₅).....	0.20
Combined Water.....	10.47
Gold.....	Trace

In this sample the iron is present principally as ferric oxide (Fe₂O₃), but an exact determination of the state of oxidation is impossible on account of the presence of arsenic, sulphur and perhaps other oxidizable elements. So far as we can see from the results of our analysis, there is nothing in the ferrous ore that should interfere with ordinary milling operations. While the ferric ore likewise contains nothing deleterious, it contains nothing valuable except a small proportion of cobalt and three ounces of silver per ton. If this is a characteristic sample, we venture to say that the ferric ore should not be included with the ferrous in milling operations.

Secondary Silver

It is generally accepted that most of the native silver at Cobalt is primary.¹

The primary character of all the silver at the Keeley mine, however, is to be doubted. Some of the silver which occurs in the weathered zone, described in preceding pages, is in all probability secondary, as was first pointed out by J. Mackintosh Bell. It would be difficult, nevertheless, to reach a definite conclusion as to what proportion of the silver in the Keeley mine is primary and what proportion is secondary.

This much may be said: In the oxidized zone, native silver in thin leaves has been found deposited on top of red iron oxides. These red iron oxides are secondary; and hence the leaf silver deposited on top of the oxides is also secondary. Very little native silver, however, occurring under this condition has been noted.

Again, soft spongy layers of native silver were noted resting loosely on top of smaltite. The sponge silver could be removed with the nail. This silver is doubtless secondary, having been leached out of the upper greatly oxidized zone and precipitated when the silver solutions came in contact with the unaltered smaltite at depth. Little of such silver was noted.

Probably the ruby silver occurring in geodes and vugs is also secondary. The wire silver, so common at the Keeley mine, is also doubtless secondary.

Beyond these statements, the writer is not prepared to go at the present time. An examination of many polished surfaces of the ore might lead to a more definite idea as to how much silver at the Keeley is primary and how much is secondary.

More light may, perhaps, be thrown on this subject when mining operations have reached the bottom of the weathered zone.

W. K. McNeill tested some of the native silver in vein No. 26 on the 480-ft. level for mercury and found it to contain a trace.

DESCRIPTION OF KEELEY MINE WORKINGS

The workings of the Keeley mine may now be described in detail, and if reference is made by the reader to the level plans accompanying this report, the descriptions will be more readily followed.

The workings from the main shaft, No. 3, will first be described, beginning with the bottom level.

Workings from No. 3 Shaft, Keeley Mine

Seventh Level, 480 Feet below Collar of No. 3 Shaft.—There are on the seventh level four productive veins, namely, Wood's; No. 26, which is sometimes called the "Birthday"; No. 16; and No. 20. This level is the richest in the mine.

Wood's is a fault vein, the displacement of which has been worked out on the level above. It dips to the east at 55° to 69° and strikes about north and south. The fault shows very little gouge or fault breccia; the gouge is for the most part but a small fraction of an inch in width, and the fault breccia some two or three inches. In the oxidized zone at the south part of the level the gouge and fault breccia are wider; in places the gouge is an inch and a half in width and the fault breccia six inches in width. Here and there in the gouge, horizontal scratches were observed; other scratches were noted dipping at 10°

¹The Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming, by Willet G. Miller, Ont. Bur. Mines, Vol. XIX, pt. II, 1913, and Guide Book No. 7, Internat. Geol. Congr. 1913, pp. 90-95.

to 15° to the north. Evidently there was some horizontal movement along Wood's vein. In places the fault contains little vein matter. North of the shaft about 80 feet Wood's vein became wider, and early in October, 1922, a high-grade shoot was discovered. Part of this shoot, for a length of 40 feet, assayed from 500 to 14,800 ounces of silver to the ton; one part of the shoot, 12 feet in length, had a width of six to fifteen inches and assayed, according to the returns of the company, 8,000 to 14,800 ounces of silver per ton. This rich shoot was in the hanging wall of the fault about two feet east of the gouge. The writer was fortunate enough to have been at the Keeley mine in October, 1922, when this shoot was discovered, and was therefore able to photograph it (Fig. 44).

At the south part of Wood's vein, a shoot of silver ore was discovered, having a length of 198 feet, which gave an average assay return of 370 ounces of silver per ton across an average width of 19 inches, according to the sampling of the company. This shoot is known as "N" shoot.

In the Keeley mine on the seventh level, there are thus two ore-shoots in the Wood's vein.

In December, 1922, vein No. 26 was discovered. In this vein was found the most consistent shoot of high-grade ore encountered in the mine up to March, 1923. It had a length of 74 feet and, according to the company reports, gave an average assay return of 2,600 ounces across an average width of 15 inches. It is reported by the management that in drifting 74 feet along this shoot the company mined 250,000 ounces of silver; no stoping was done to recover this output. At one place this wonderful shoot had a width of about five feet, but this width was only local and appeared to be due to a sudden swell in the vein, combined with a sharp bend (Fig. 50).

Vein No. 26 is at the south part of the level. It is a branch of Wood's vein and very gradually leaves this vein, almost paralleling it for about 60 feet, at a distance of 2 to 5 feet. Vein 26 then turns to the northwestward, just about the point at which the ore-shoot began to develop. The writer examined the vein on January 24th and 25th, 1923. At that time it showed very little calcite, but was characterized by a high percentage of smaltite, some of which occurred in vuggy, kidney-like, or grape-like rusty masses. The native silver, in places, was noted to occur in thin leaf-like forms in vugs, and on top of the kidney-like or grape-like masses of smaltite. Vein No. 26 appears to occur in a fault of small though unknown displacement.

At the south end of the level, vein No. 20 was discovered early in the year 1923. It is a branch of Wood's vein on the east side and strikes eastward. The writer has not seen this vein, but it is reported to contain high-grade ore, the native silver occurring in "matted" forms.

Vein No. 16 is a branch of Wood's vein. It leaves the latter in a gentle curve and finally strikes westward, about at right angles to Wood's vein. In October 1922, the vein had been followed westward for 225 feet. It is in Nipissing diabase for some distance west of Wood's vein. Where the vein occurs in the diabase it is vertical, but where it enters the Keewatin it dips at an angle of about 60° to the south. This southerly dip is due to the fact that where the vein enters the Keewatin it follows the footwall of a mica-lamprophyre dike and, as the dike dips to the southward at 60°, so the vein also has this dip. It is another instance, so common in the Cobalt area, of a vein following the strike and dip of a lamprophyre dike. In every case, of course, the lamprophyre dikes are younger than the Keewatin, but older than the Nipissing diabase. At the time of our examination in October 1922, vein No. 16 had been traced for 100



Fig. 50—Keeley mine, vein No. 26, 480-ft. level, January 24th, 1923. The vein is four to five feet wide on this face, but pinches out rapidly to normal size. The ore averages 7,000 ounces of silver per ton. Leonard G. Smith at the right. Photographed by Cyril W. Knight.

feet along the footwall of the lamprophyre dike. Vein No. 16 is a fault vein; it has faulted the contact of the Keewatin and Nipissing diabase about two feet horizontally, the vertical movement not having been ascertained. The fault breccia is six inches wide in places. A stope section along vein No. 16 is shown in the drawing facing page 207.

Weathering and oxidation of Wood's vein and wall-rock first develops about 75 feet south of vein No. 16, where there is a zone of red oxidized material about 15 feet in length. The back of the drift along this 15-ft. zone had soft and dangerous rock, necessitating some timbering. South of this small oxidized portion weathering almost ceases for about 50 feet, when it again develops, and in places the Nipissing diabase is altered to a more or less soft green clay for a width of at least 4 or 5 feet in places. Most of the oxidized material has a pale greenish-grey colour, although some is coloured reddish-brown due to ferric oxide.

An analysis of the weathered Nipissing diabase at the south part of Wood's vein was made by W. K. McNeill, Provincial Assayer, and T. E. Rothwell. The specimen analyzed was a clayey material having a pale greenish-grey colour; and although the rock minerals were apparently almost entirely altered to kaolin the specimen still preserved its diabase texture.

ANALYSIS OF GREENISH-GREY CLAYEY MATERIAL (ALTERED NIPISSING DIABASE), KEELEY MINE,
480-FT. LEVEL, WOOD'S VEIN, IN OXIDIZED ZONE

	Per cent.
Silica.....	44.76
Alumina.....	25.06
Ferrous oxide.....	5.23
Ferric oxide.....	5.54
Lime.....	5.76
Magnesia.....	3.12
Potash.....	1.64
Soda.....	1.44
Carbon dioxide.....	0.28
Water.....	7.42

100.25

Vein No. 26 is stained here and there with red oxides, but the weathering of the wall-rock is not marked.

On levels above, the red oxides of iron are more common in the weathered zone than they are on the seventh, 480-ft. level.

Much water was encountered in certain parts of the oxidized portion of Wood's vein; on October 23rd, 1922, the flow taxed the capacity of the pumps. More water was encountered in the weathered part of Wood's vein on the various levels than was met with in the unweathered portions of the vein at the north part of the workings.

The workings on the seventh level are almost entirely in the Nipissing diabase sill. All of Wood's vein is in the diabase. The Keewatin was met with in the drift along vein No. 16, about 100 feet west of Wood's vein; the Keewatin was also met with in the drift on vein No. 28 west of Wood's vein. The dip of the diabase contact where it occurs in the drift along vein No. 16 is about vertical, but this vertical contact is, presumably, a local irregularity.

Sixth Level, 418 Feet below Collar of No. 3 Shaft.—The productive veins on the sixth level are Wood's, No. 16, and No. 6.

Wood's vein marks the contact between the Nipissing diabase and the Keewatin. In October, 1922, the vein had been drifted on for nearly 700 feet, disclosing Nipissing diabase on the hanging wall, east side, and Keewatin basalt

on the footwall, west side, except at the north and where the diabase forms both hanging wall and footwall. The contact of the top of the diabase on the footwall dips, at the north end, at an angle of 10° to the south (drawing facing page 216).

Wood's vein is in a fault. As far as could then be determined, the fault is a reverse one, with a displacement of about 30 feet, more or less, along the plane of the fault (drawing facing page 207). But horizontal scratches on the walls of the fault on the level below show that some horizontal movement has taken place. Sufficient work, however, had not been done to definitely determine the exact displacement, either along the dip or along the strike of the fault.

Wood's vein on this level is, in places, a strong one, showing at one point 12 to 15 inches of smaltite; in other places there is little or no vein matter. At the north part of the drift, the vein apparently leaves the fault for about 50 feet and enters the hanging wall, finally, however, entering the fault again farther north, as shown by the plan of this level. North of this there are vugs in the fault, and some beautiful crystals of argentite and ruby silver were found in these vugs.

The fault breccia varies in width from two to fifteen inches; it will average probably less than three or four inches. The gouge is but small fractions of an inch in width, showing in one place, however, a width of an inch.

Weathering and oxidation along Wood's vein and wall-rock on the sixth level begins about 20 feet south of the crosscut which runs from No. 6 vein to Wood's vein. The oxidation increases in intensity towards the south, until on the face there are three feet or more of soft, brownish-red decomposed rock. In places the hanging wall of Nipissing diabase is completely altered to the soft, clay-like material with a pale, greenish-grey colour, already mentioned, which still retains the diabase texture of the original rock. At the south end of this oxidized zone some very rich lenses of silver ore, a few feet long and one to three or four inches wide, were met with. In this part of the fault there were found lenses of smaltite; and in cracks in the smaltite, there occurred plates of soft, spongy silver. This silver could readily be removed from the smaltite with the finger. Such occurrences of silver, in cracks in the smaltite, are apparently of secondary origin. The silver was probably dissolved out of the upper part of the vein in the oxidized zone and carried down and re-deposited on the smaltite. In this part of the vein there is much wire silver, growing in geodes in the smaltite.

Vein No. 16 is an important one on this level, although it has not yet been so productive on other levels. It leaves Wood's fault in a gentle curve and is evidently a branch of Wood's fault, running at about right angles to it. Immediately west of the fault, a rich shoot was encountered in No. 16 vein. The stope in this shoot is only 30 feet long and 25 feet high, yet it produced about 150,000 ounces of silver. The vein in this stope was in places 12 inches wide of smaltite. The shoot did not extend quite up to Wood's vein, but a small calcite stringer did enter the latter. The vein had been followed west for some distance, and two more shoots of less importance were found (drawing facing page 207). The vein in the drift, west of the rich shoot, is a strong calcite vein showing in places a width of 15 inches. It follows a mica-lamprophyre dike, as on the seventh level. The vein is sometimes on one wall of the dike and sometimes on the other.

Vein No. 16 is evidently a fault vein, as there is about half an inch of fault breccia and gouge in the fissure. On the seventh level the fault has a horizontal displacement of about two feet.

Vein No. 6 is a strong, white calcite vein up to a foot in width, dipping 70° to the east. In places the vein is almost frozen to the walls, while elsewhere

there are from one to perhaps three inches of fault breccia and gouge. On the fifth level, 35 feet south of the shaft, a winze was put down on No. 6 vein. In this winze, 17 feet below the fifth level on the east side of the vein, the top of the Nipissing diabase sill was met with; while on the west side of the vein the Nipissing diabase was encountered 19 feet below the fifth level. Thus, vein No. 6 is in a reverse fault which has displaced the diabase contact two feet (drawing facing page 207).

Fifth Level, 355 Feet below Collar of No. 3 Shaft.—Nearly all of the level is in Keewatin, cut by lamprophyre dikes. A little Nipissing diabase occurs at the shaft and in two nearby drifts. Opposite the shaft the contact between the Nipissing diabase and Keewatin is vertical, but this is a local irregularity.

Wood's vein varies in width from an inch or two to about a foot. The fault in which it occurs shows about one to three or four inches of fault breccia and gouge. In places the vein consists of a number of small, irregular stringers which evidently, in part at any rate, replace the wall-rock, which is somewhat schistose. Here and there a lamprophyre dike was noted along the walls of the vein on this level. In places a little pink feldspar occurs in the vein. The south end of the vein and wall-rock is oxidized, the intensity of oxidation increasing towards the south.

Vein No. 16 is a strong vein, up to 18 inches wide, of white calcite; and at one place 30 feet west of Wood's fault, 12 inches of pure smaltite was exposed; some high-grade silver ore also occurred here. The vein follows a mica-lamprophyre dike, as it also does on the two levels below. On the west face there was half an inch of gouge in the fault in which this vein occurs.

No. 6 vein is a strong one, four to six inches wide, having in places a width of 12 to 18 inches of calcite. In places it splits into six parallel stringers. A stope has been worked on this vein.

Fourth Level, 296 Feet below the Collar of No. 2 Shaft.—This level is not connected directly with No. 3 shaft. It is reached by a winze from the third level. The rock consists of Keewatin basalt cut by lamprophyre dikes.

The fourth level had, up to November, 1922, proved to be barren. The work had been done wholly on Wood's vein, the drift on the vein being 550 feet in length. The vein is a strong one, at one point showing four feet of white calcite. It has in places a finely banded texture, due to the interbanding of pink and white calcite, as many as 50 bands or more having been counted across six inches. There is in places a pink, fine-grained variety of calcite in the vein, a sample of which was submitted to W. K. McNeill for analysis, the result of which was as follows:—

ANALYSIS OF FINE-GRAINED, PINK CALCITE, KEELEY MINE, 296-FT. LEVEL

	Per cent.
SiO ₂	0.20
MgO.....	0.16
CaO.....	53.91
MnO.....	0.10

The vein is not always in the fault. It leaves the fault at times, and parallels it at a distance of three feet or so in the hanging wall.

The gouge and fault breccia have a combined width of two or three inches.

The south end of the drift is oxidized for 200 feet, the intensity of the oxidation increasing towards the south. On the south face of the drift there is one foot of soft clay, stained brown or yellow; on each side of this clay, the walls are still hard but are stained with iron oxides.

Third Level, 235 Feet below the Collar of No. 3 Shaft.—This level is all in the Keewatin basalt, cut by lamprophyre dikes of Haileyburian age. It is one of the most extensive workings in the mine, the Wood's vein having been drifted on for about 1,200 feet. The Wood's vein, as on lower levels, pinches and swells, and is as wide as 15 inches in places.

The south part of Wood's vein and adjacent country rock is oxidized and weathered for 600 feet. Oxidation begins about 125 feet south of the crosscut which goes to the main shaft. The oxidation is at first not marked. It first becomes evident by the appearance, in cracks and joints of wall-rock and vein, of reddish-brown limonite together with the earthy variety of limonite which has a brownish-yellow and ochre-yellow colour. Proceeding south along the drift, this oxidation becomes more intense. The wall-rock gradually turns soft, until finally in places the rock is almost completely decomposed to a soft clay. In some places the rock is altered to this soft material across a width of four feet. The decomposed and oxidized rock, fault breccia, and vein material have for the most part a reddish-brown colour. In places the material has a pale grey colour, tinted with pale green. The lamprophyre dike, which here and there forms the wall-rock of Wood's vein, appears to have weathered more readily than the hard, tough basalt. At one place a sample of this altered lamprophyre was taken and submitted for analysis to W. K. McNeill, Provincial Assayer, and T. E. Rothwell, who found it to have the following composition. It will be noted that the iron occurs almost wholly in the ferric state, Fe_2O_3 , probably accounting for the red colour.

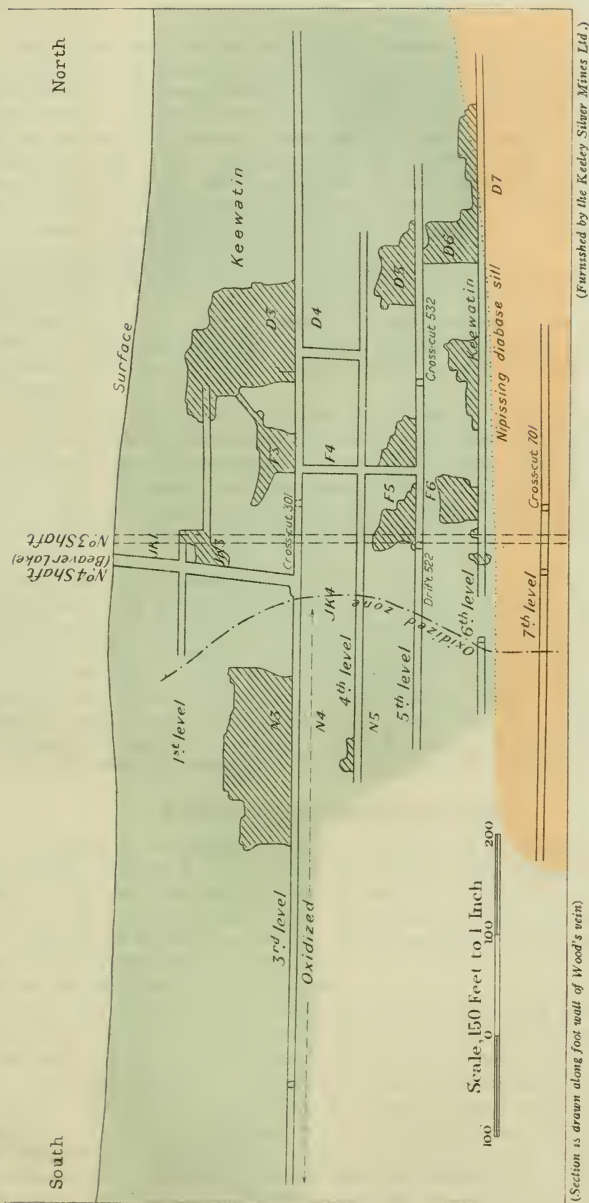
ANALYSIS OF REDDISH-BROWN CLAYEY MATERIAL (ALTERED MICA-LAMPROPHYRE DIKE)
KEELEY MINE, 235-FT. LEVEL, WOOD'S VEIN, IN OXIDIZED ZONE

	Per cent.
Silica.....	44.30
Ferric oxide.....	13.37
Ferrous oxide.....	Trace
Alumina.....	24.19
Lime.....	1.25
Magnesia.....	2.24
Soda.....	0.72
Potash.....	0.32
Water.....	12.97
Carbon dioxide.....	0.90
Total.....	100.26

Some of the pale greenish-grey clay in the oxidized zone of Wood's vein was tested by W. K. McNeill, who showed that this clay contained the iron largely in the ferrous state, while in the red and brown clay the iron is largely in the ferric state.

In the south part of Wood's vein, there is a stope 175 feet long and 75 feet high in the oxidized portion of the vein. In this stope the width of the oxidized zone varies; in places it is but six inches wide. In December, 1921, a little of the oxidized ore was being treated in the mill, but in November, 1922, none of this material was being used. It is difficult to treat with the present process in use at the mill, and some other method will be adopted for treating it.

In the stope referred to above, there are, here and there, thin films of native silver deposited on top of films of reddish-brown oxide of iron. As these oxides are certainly secondary, it follows that this leaf silver must also be secondary in origin. This secondary silver has probably been leached out from portions of the vein higher up.



STOPE SECTION ON WOOD'S VEIN, KEELEY MINE
SOUTH LORRAIN, DISTRICT OF TIMISKAMING, ONTARIO

To accompany Ontario Department of Mines Report, Volume XXXI, Part 2, 1922, by Cyril W. Knight on the Cobalt Silver Area.

Wood's fault near the south end of the drift branches, one branch continuing southward along the general strike of the vein and the other turning and striking southeastward. The southeast branch, judging from the fault breccia, is the stronger fissure. On the south face of this southeast branch, the rock is decomposed across five or six feet to a soft, grey, clay-like material. This branch of the fissure contains a rusty quartz vein one to six inches wide, carrying here and there galena, zinc blende, and iron pyrites. It is curious that some of these sulphides should be perfectly fresh, while the country rock is so much decomposed that it is now altered in places to a soft, clay-like substance. In the fault breccia there is much reddish-brown (ferric) material.

No. 6 vein is in a minor fault, as evidenced by a small gouge and breccia one-half to one inch wide. The vein in this fault may average two or three inches in width, and is as wide as six inches. In places there is no vein material whatever in the fault. The vein and fault breccia are slightly oxidized, beginning about 125 feet south of the shaft. In this part much cobalt bloom occurs along the vein.

Second Level, 164 Feet below the Collar of No. 3 Shaft.—The level is in Keewatin basalt. No. 6 vein is a strong-looking calcite vein one to eight inches wide. It contains some small shoots of smaltite a few feet in length, but carries no silver. No. 6 vein and its branch, No. 9, have been drifted on for 300 feet. No. 6 shows a fault breccia and gouge about half an inch in width. The south end of No. 6 vein and country rock is oxidized for 50 feet. Wood's vein was not worked on this level.

First Level, 100 Feet below Collar of No. 3 Shaft.—This level is in the Keewatin basalt. No. 6 vein and its branch, No. 9, have been worked. No. 6 averages in width from two to three inches of calcite and is wider in places. No. 9 vein is 12 inches in width in places, consisting of calcite; it also shows four inches of smaltite in one place. South of the shaft there is a stope on No. 6 vein about 30 feet long and some 15 feet high. It is reported that one of the old companies obtained a small quantity of silver from this stope. No. 6 vein shows evidence of movement along the wall; there is a fault breccia of about an inch. The vein dips 75° westward, whereas on the sixth level it dips eastward.

Workings from No. 4 Shaft (Beaver Lake)

No. 4 shaft is also called the Beaver Lake shaft, it having been sunk on the Beaver Lake claim, H.R. 21, which is now a part of the Keeley Silver Mines, Limited. The shaft was sunk on Wood's vein and is, therefore, an inclined one, as the vein dips eastward about 65°. There are two levels, namely the 74-ft. level, and the 98-ft. level, known as the intermediate. These two levels are shown on the plan of the third level of the No. 3 shaft. The No. 4 shaft extends down to the third level of the No. 3 shaft.

74-ft. Level.—This is a short level and consists of a drift 120 feet long on Wood's vein. Had the original workers continued the drift a short distance farther north, an important high-grade shoot of ore known as "D3" would have been encountered, although it is largely on the original Keeley claim H.R. 19.

98-ft. (Intermediate) Level.—This level was run by the present operating company, and on it was encountered the high-grade shoot of ore known as "D3" referred to in the preceding paragraph. The shoot was 60 or 70 feet long and was one of the longest high-grade shoots in Wood's vein. The back of the stope was, at the time of our examination in October, 1922, about 55 feet below the surface (stope section facing page 216).

Workings from No. 1 Shaft, Original Discovery, Keeley Mine

The mine workings from No. 1 shaft are those which were first worked by interests connected with the Farmers Bank. The original discovery was made there by J. W. Wood and R. J. Jowsey. The present company has not attempted to operate these old workings.

On October 28th, 1922, the writer made an examination of these workings. The levels were fortunately all accessible, owing to the fact that the water was kept pumped out for use on the property. The old workings are distinct and separate from the later workings, and have not been connected with the latter. No silver production has come from them since the present company bought the property. Including drifts, crosscuts, and shafts, the length of the workings amounts to some 1,800 feet. They are in Keewatin basalt and Nipissing diabase, the first 168 feet of the shaft being in Keewatin. The top of the Nipissing diabase sill was encountered at this depth, and the work below this, on the third level, was all done in the diabase. The workings show that the contact of the diabase and Keewatin dips at about 28° to the west.

There are three levels, at 61, 131, and 206 feet, respectively, below the collar of the shaft. No stoping was done on the third level. There is a small stope about 25 feet long in Keewatin on the second; and there are four stopes on the first level, the largest of which is about 90 feet in length, all in Keewatin. The first level was the only one of importance as far as production is concerned.

These old workings produced 24,337 ounces of silver, according to the records of the Ontario Department of Mines.

Beginning with the bottom level the following notes may be of interest:—

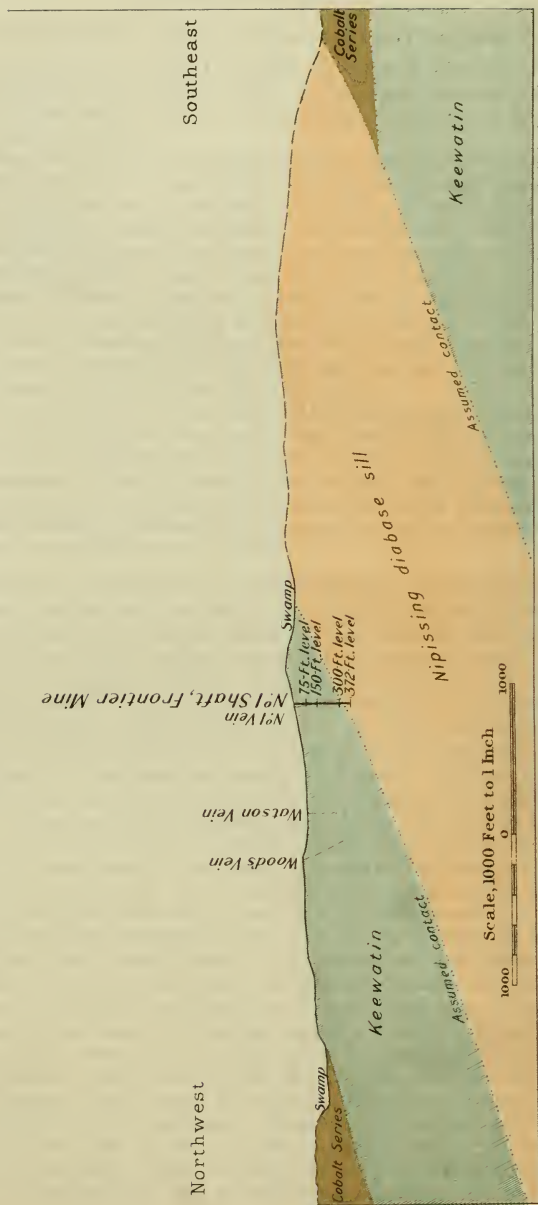
Third Level, 206 Feet below the Collar of No. 1 Shaft.—The level is entirely in the Nipissing diabase, at the top of the sill. The contact between the diabase and Keewatin in the shaft is approximately 38 feet above the level.

There are some twelve veins on the level, consisting of pink and white calcite, barren of silver. They are more or less parallel and strike west 10° to 30° north. The veins are mostly from a half to an inch or two in width; the largest is No. 1 A vein at the shaft which is from a half to four inches in width.

Second Level, 131 Feet below the Collar of No. 1 Shaft.—The west part of the level is in Keewatin, and the east part in Nipissing diabase, the contact dipping 26° westward. Practically all the work has been done on No. 1 vein which, west of the shaft, shows in one place five parallel veins from one-half to three inches in width, one of them showing two inches of smaltite and niccolite. A stope about 25 feet long occurs here. East of the shaft this vein is scarcely more than a pronounced joint crack, showing evidence of a little movement.

At the east end of the workings, No. 8 vein is a fault vein dipping 60° south-west. It carries a little cobalt bloom. The work on the level below had not been, it would seem, carried far enough northeast to encounter this vein.

First Level, 61 Feet below the Collar of No. 1 Shaft.—Most of the silver production came from the first level. It is almost wholly in Keewatin, except about 20 feet at the southeast corner of the workings which is in Nipissing diabase. No. 1 vein at the shaft has a stope about 90 feet long and some 30 feet high, as far as could be ascertained. No. 8 vein at the northeast part of the workings is a fault vein with a dip of 80° to 90° southwest. There are two stopes on this vein, one 20 feet long and the other 15 feet. A vein at right angles to No. 8 vein has a stope about 20 feet long. There are thus four stopes on the first level. The veins, as far as could be seen, vary in width from fractions of an inch to four inches.



VERTICAL SECTION THROUGH NO. 1 SHAFT, FRONTIER MINE
SOUTH LORRAIN. DISTRICT OF TIMISKAMING, ONTARIO

To accompany Ontario Department of Mines Report, Volume XXXI, Part 2, 1922, by Cyril W. Knight on the Cobalt Silver Area.

Frontier and Crompton

In 1922, the Mining Corporation of Canada, Limited, was working the Frontier and Crompton properties. The number of the Frontier claim is H.R. 16, and that of the Crompton, H.R. 25. The Crompton is a narrow claim, about 500 feet wide, between the Frontier on the north and the Keeley on the south. Both properties are worked from the same shaft, namely, No. 1. In the spring of 1923, however, a new shaft, No. 3, was begun.

The Haileybury Silver Mining Company originally owned H.R. 16. In the year 1909, this company sold the south half of the claim, 20 acres, to the Haileybury Frontier Mining Company. The Mining Corporation of Canada, Limited, subsequently bought the north and south half of H.R. 16, and this claim, H.R. 16, is now generally referred to as the Frontier. The company also owns the Little Keeley, H.S. 40, north of the Frontier, and the Forneri, H.S. 42, north of the Little Keeley. Other claims have been acquired.



Fig. 51—Frontier mine on left, Keeley mine on right.

Examination of the property was made in the fall of 1921 and 1922, and a brief visit was paid in May, 1923.

The ore-shoots at the Frontier mine, like those at the Keeley, occur at the top of the Nipissing diabase sill, both in the diabase and in the overlying Keewatin.

Almost the entire surface of the Frontier and Crompton is composed of Keewatin basalt, showing in places pillow structure, and volcanic fragmental rocks. The Keewatin is cut by lamprophyre dikes of Haileyburian age. At the southeast corner of the Crompton, the top of the Nipissing diabase sill is exposed. The mine workings prove that the diabase dips under the Keewatin rocks. No. 1 shaft of the Frontier, for example, passes through 322 feet of Keewatin and then encounters the top of the Nipissing diabase sill; the diabase is thus proved to dip under the Keewatin at an angle of about 25° (drawing facing page 219).

There are four main veins on the property, namely, No. 1, the Watson, Wood's, and the Haileybury Silver. Of these veins, Wood's has proved to be the most productive, up to the end of April, 1923.

The mine, referring to the Frontier and Crompton, is worked from No. 1 shaft, and has four levels, which are 75, 150, 300, and 372 feet, respectively, below

the collar of the shaft. There is also a shallow shaft, No. 2, on the Wood's vein; and a shaft on the Haileybury Silver vein, now no longer in use.

At the end of April, 1923, fifteen shoots of high-grade silver ore had been met with, two of which were on the Crompton, and the remainder on the Frontier. Three of these were on the second level, but were small and unimportant. The remaining twelve shoots were on the third level; one of them occurred in Wood's vein, another in the Watson vein, and the other ten were in No. 1 vein.

The longest silver shoot was in Wood's vein, at the south end of the Crompton; this shoot had a length of 102 feet and an average height of 35 feet, although it was 57 feet high in one place. The shoot produced to the end of April, 1923, approximately 900,000 ounces of silver, and was the most important ore-shoot in the mine up to that time. At one place the vein was 40 inches wide, of which 36 inches consisted of high-grade, the remaining four inches being calcite. When the writer examined this stope on May 7th, 1923, the vein in the back showed 30 inches of high-grade silver ore in one place (Fig. 52).

Of the other silver shoots one was about 60 feet in length. The shoot in the Watson vein was only 30 feet long and 22 feet high, but it produced approximately 125,000 ounces of silver. Some of the other shoots appeared to have a length of only a few feet.

All of these ore-shoots occur within 100 to 200 feet of the contact between the top of the Nipissing diabase sill and the Keewatin; most of them are within 100 feet of the contact.

The tendency of No. 1 vein to follow a lamprophyre dike may be noted. This dike was observed here and there along the drifts which follow the vein; and on the third level an attempt was made to map it.

Pre-Glacial Weathering

In places the lamprophyre dike referred to in the preceding paragraph is decomposed to a soft clayey material, having a pale, greenish-grey colour. Possibly this alteration is all that now remains of the deep-seated portions of pre-glacial weathering.

Early History of Frontier Mine

As the early history of a mine is always of interest, the writer asked Mr. Horace F. Strong if he would give the Department an account of how he became interested in the Frontier, how he found certain ore-shoots, and how he was instrumental in turning the property over to the Mining Corporation of Canada, Limited. The Department is indebted to Mr. Strong for the following account of the early history:—

What is now known as the Frontier mine was originally the south half of the property of the Haileybury Silver Mining Company's claim, No. H.R. 16. It contains about twenty acres, and is situated to the north of the Keeley claim and separated from the same by the Crompton fraction. The latter is about 500 feet wide.

One, Henry Newburger, of Memphis, Tenn., bought the south half of H.R. 16 from the Haileybury Silver Mining Company in 1912 for \$100,000 cash and formed the Haileybury Frontier Company. This company sank two shafts, one to the southwest to a depth of ninety feet and one near the northern boundary to a depth of 150 feet. From the latter was done about 100 feet of crosscutting and fifty feet of drifting on the 75-foot level, and about 250 feet of drifting on the 150-foot level. Both levels showed a strong vein carrying smaltite, but no silver was in evidence. In the meantime Henry Newburger died and the company went into liquidation in 1914. Joseph Newburger, a cotton king of Memphis, Tenn., and brother of the deceased, bought in the property in the interests of his brother's widow, and the mine remained closed until the autumn of 1920. During the summer of 1920, Joseph Newburger had the mine dewatered and examined by representatives of several silver-mining companies. At this time J. G. Harkness, who had dewatered the mine, had collected options on control of the Haileybury Silver property and advised Mr. Newburger to purchase same. The latter, however, failed to do so and after a couple of weeks allowed the Frontier to fail.

During the autumn of 1919 and spring and summer of 1920, the writer was doing considerable investigation into the various sources of cobalt ore for a large consumer of the metal in the U.S.A., and during a shortage had supplied his client with several carloads of high cobalt, low silver ore. During the month of August, 1920, the situation became so acute that the writer asked his client to be allowed to purchase the Haileybury Silver and Frontier properties, using the argument that several hundred tons of high cobalt, low silver ore could be cheaply developed, with reasonable chances at the same time of running into shoots of high-grade silver ore. The force of the argument was seen, and the writer was allowed to proceed. The Haileybury Silver property was bought outright early in September for \$15,000 cash, and negotiations started for the Frontier. The latter proved more difficult, but eventually, in November, 1920, the writer had secured a reasonable lease for a year and further option to purchase. Dewatering was proceeded with immediately, and the first machine started on December 16th. A thorough sampling of the old working showed a short shoot of mill ore on the 75-foot level. Drifting proceeded at the rate of 200 feet per month until May 1st, 1921, and the work put into sight about 400 tons of high cobalt, low silver ore, and two short shoots of 500-ounce silver ore.

Having worked out the geology of the property, the writer prevailed upon his client, the cobalt ore situation being in the meantime settled temporarily, to allow the 150-foot shaft to be sunk to the contact zone. This entailed a further 150 feet of sinking and 27 feet of crosscutting. The sinking was very much retarded by extremely hard rock, the Keewatin greenstone proving very baffling. Eventually the desired horizon was reached about the end of August, and the vein cut within a few inches of the projected point. A short patch of high-grade silver was encountered in the second or third round of the drift, and in 300 feet of drifting, driven during September and October, at least 200,000 ounces in high-grade was indicated. The writer then put two propositions before his client. First, that he should put up an additional \$200,000 for the purchase of adjoining properties, install a suitable mining plant, etc., and proceed to develop and mine on a larger scale, or, second, to sell the property. The latter course was decided on, and in November, 1921, the writer concluded the sale under option to the Mining Corporation of Canada, Limited, at a price of \$525,000 over a period of two years.

Description of Frontier Mine Workings

Commencing with the bottom level, the mine workings may now be described.

Fourth Level, 372 Feet below Collar of No. 1 Shaft.—This was the bottom level of the Frontier mine in April, 1923. There were about 2,600 feet of workings. The northeast half of the same is in Nipissing diabase, the remainder in Keewatin. The contact between the diabase and Keewatin dips about 15° to the southwest. The Keewatin consists of basalt, cut by lamprophyre dikes of Haileyburian age.

No. 1 vein averages two or three inches in width, swelling in places to 12 or 15 inches. It consists for the most part of pink and white calcite, and strikes southwestward. It contains a few small shoots of almost pure cobalt ore and niccolite, but is barren of silver, excepting for the presence of one small sample. It is wider in the diabase than in the Keewatin. Its contacts with the wall-rock are frozen.

The Watson vein was also barren of silver on this level. It is 2 to 4 inches or more in width and is vertical. A little movement appears to have taken place in the fissure which contains the Watson vein, as shown by a gouge about one-quarter of an inch wide, and a fault breccia an inch or two in width. In places the joint planes, adjacent to the vein, are lightly covered with thin films of red iron oxide. There are vugs in the Watson vein.

Third Level, 300 Feet below Collar of No. 1 Shaft.—This was the most extensive and most productive level in the mine; in April, 1923, there were about 2,850 feet of workings. The Nipissing diabase was met with about 40 feet northeast of the No. 1 shaft. The contact of the diabase and Keewatin occurs in the shaft about 22 feet below the third level. The rest of the level to the southwest is all Keewatin basalt, cut by Haileyburian lamprophyre dikes.

An attempt was made to map an irregular hornblende-lamprophyre dike which appeared parallel to No. 1 vein in the vicinity of the winze. This winze is about 230 feet southwest of No. 1 shaft. The lamprophyre dikes occur in various parts of the level. They are irregular intrusions, difficult to map after the walls

have become covered with rock dust following blasting. Some of the dikes are sill-like in form, that is, they have flat dips. Towards the southwest end of No. 1 vein, a lamprophyre dike is decomposed to a soft rock.

The presence of a dike of pink feldspar-porphyry was noted about 60 feet southwest of the winze referred to in the preceding paragraph. Presumably it cuts the lamprophyre, although the relationship was obscure owing to rock dust on the walls and back, and the small exposure.

In No. 1 vein, ten high-grade shoots of silver ore had been met with. The vein is a strong one, in places up to a foot in width, but towards the southwest end, before entering the Watson, it is but an inch or two in width, and in places is little more than a crack. There appears to have been no movement along the crack in which the vein occurs. Little or no gouge or fault breccia was noted.

What appeared to be the longest of these shoots in No. 1 vein occurred about 230 feet southwest of the shaft. A winze was sunk on this shoot, and it was found to extend about 40 feet below the third level. This shoot of high-grade silver ore averaged five or six inches in width on the northeast face of the winze. It was wholly in the Keewatin rocks, and did not extend down to the fourth level where the Nipissing diabase occurred. A small fault, with only fractions of an inch of fault material, intersected the vein, displacing it about an inch. The rich ore occurs above and below the fault. At the time of examination, in the middle of October, 1922, the ore-shoot had not been mined, save for the ore taken out of the winze.

The Watson vein strikes about north and south, bending southwestward at the south end. North of its junction with No. 1 vein, it is a strong calcite vein up to a foot in diameter, and, in places, contains smaltite six inches to a foot in width. This part of the vein is characterized by the presence of many irregular vugs lined in places with arsenides on which have grown calcite crystals. One of these vugs rises at least five feet above the back of the drift, and is six inches wide.

The Watson vein, south of its junction with No. 1 vein, may average an inch or two in width of banded calcite, bulging in places up to five or six inches. The banding consists of alternate layers of pink and grey material, as many as 30 or 40 bands to an inch. About 260 feet south of its junction with No. 1 vein, a wonderfully rich shoot of high-grade silver ore was met with. This shoot is reported to have produced 125,000 ounces of silver, and was only 22 feet high and 30 feet long. In one place it was said to be 23 inches wide. The ore consisted mainly of smaltite and native silver.

To the south of this stope the Watson vein is weak-looking, and along most of the distance is a mere rock. In one place vugs of calcite were noted.

The Watson vein is a fault vein; this is shown by the presence of gouge, small fractions of an inch in width, and a fault breccia of an inch or two in width; in places the fault breccia is wider than this. The displacement along the fault is not known. A lamprophyre dike was noted here and there along the Watson vein; it was not determined whether the dike was continuous along the vein. Pink feldspar was noted in the latter.

Wood's vein is about 300 feet west of the Watson vein, and it strikes about north and south, dipping 65° to the eastward. It is difficult to say what is its average width; in the stope at the south end, described below, it is 40 inches wide in one place, but it is doubtful whether the width of the vein will average more than a few inches along the whole length. It consists mostly of pink and white calcite, in places finely banded. Some pink feldspar occurs here and there. About an eighth of an inch of gouge and three or four inches of fault breccia occur in the fault; in places the fault breccia is wider.

The longest and most important shoot in the mine occurs in Wood's vein at the south end of the workings, near the Keeley boundary line. As stated elsewhere in this report, the stope on this level is 102 feet long with an average height of 35 feet; 900,000 ounces of silver had been mined from the stope to the end of April, 1923. The stope produced some very fine specimens of argentite with wire silver "sprouting" from the argentite. These specimens occurred in vugs in the vein.

A lens of cobalt ore occurs in Wood's vein at the north part of the workings.

On the third level, at the northeast end, two prominent faults occur. The first one is 90 feet north of the shaft, and was drifted on for about 90 feet. It strikes about east and west, and is almost vertical, dipping steeply to the north. This fault has about an eighth to a quarter of an inch of gouge, and six to eight inches of fault breccia. No. 1 vein passes through the fault, and high-grade ore was found north of it, and for a few feet south. At the time of examination a



Fig. 52—Wood's vein, Crompton mine, 300-ft. level, back of stope; showing a width of 30 inches of high-grade silver ore. Photograph furnished by the Mining Corporation of Canada, Limited.

stope was being worked in this ore-shoot, which had reached a height of about 25 feet and a length of about 25 feet.

At the top of this stope, the second fault, dipping about 34° to the northwest, was met with. This fault had a fault breccia about a foot wide. The vein had not been found above this fault at the time of examination. That the fault was older than the ore deposits appeared to be shown by the presence of leaf silver and ruby silver in the fault breccia, in which these two minerals had evidently been deposited. But there was some later movement which faulted the vein a little. This fault was followed on the level in a drift which begins 50 feet north of the shaft. In this drift the fault breccia is 6 to 24 inches wide. It appears to be an important fault.

Second Level, 150 Feet below the Collar of No. 1 Shaft.—This level is entirely in Keewatin-basalt, but is cut by younger dikes of feldspar-porphry and lamprophyre. Towards the south end of the workings, No. 1 vein appears to follow an irregular lamprophyre dike:

No. 1 vein has been followed for about 1,000 feet, but only three small, unimportant shoots of high-grade silver ore were found. The vein may average two inches, and is five or six inches wide in places, but it is merely a crack elsewhere. At times the vein contains small lenses, five or six inches wide, of cobalt ore.

At the shaft, No. 1 vein encounters a well-defined fault, showing several inches of gouge and breccia, and there is an apparent horizontal displacement of about 30 feet.

At the north end of the workings there is what is known as the Haileybury silver vein. It is a barren pink calcite vein dipping 70° to the northeast. There is a raise or shaft to the surface; some cobalt ore was obtained in the raise years ago.¹

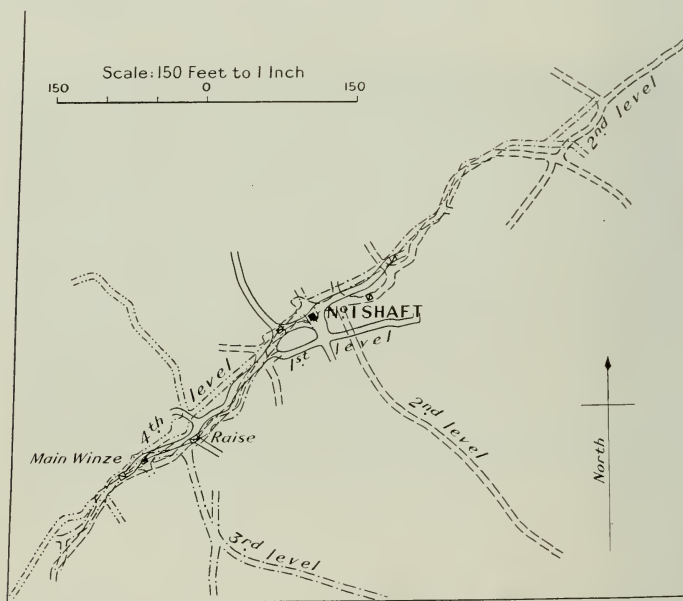


Fig. 53—Plan showing mine workings of Wettlaufer. Furnished by Mr. Horace F. Strong.

First Level, 75 Feet below Collar of No. 1 Shaft.—Only about 250 feet of work has been done on this level, partly on No. 1 vein and partly on a fault which meets the vein not quite at right angles. The vein is about six inches wide and appears to follow a lamprophyre dike. The workings northeast of the shaft were not accessible.

Wettlaufer

The Wettlaufer claim, H.R. 85, is contiguous to the Keeley on the southeast.

The mine had, up to the end of the year 1922, the largest production of silver in South Lorrain, the output amounting to about 2,564,584 ounces at that

¹The Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming by Willet G. Miller, Annual Report of the Ont. Bur. Mines, 1913, Vol. XIX, pt. II, p. 143.

date. It has not, however, yielded much silver since 1913, although it has been worked on and off since then.

The property was idle and flooded at the time it was visited in the fall of 1922, and hence it was impossible to examine the mine workings.

From information gathered from various sources, it appears that there is practically one vein on the property. This vein occurs only in the top of the Nipissing diabase sill, and does not extend into the overlying Keewatin, in which respect it differs from veins on the Keeley and Frontier, which occur both in the diabase and overlying Keewatin. One may note on the surface that the vein does not enter the Keewatin.

The Wettlaufer vein strikes about north 60° east. It outcrops along the side of the Wettlaufer valley, and it enters the valley at a gentle angle. The Wettlaufer valley probably represents a fault; and as it strikes north 41° east, it is seen that if the vein continues far enough to the northeast with a strike of north 60° east it would gradually enter the Wettlaufer valley fault.

It is reported that silver occurred on the surface in the Wettlaufer vein. The vein may still be examined on the surface, and in places shows a width of one to three inches of smaltite. Quartz is also found in the vein, stained with cobalt bloom and having a width of two inches.

The vein runs about at right angles to the contact between the Nipissing diabase and the Keewatin.

The writer is indebted to Horace F. Strong, who was manager of the Wettlaufer at one time, for his kindness in writing the following description of the underground geology:—

The Wettlaufer mine was one of the early discoveries of high-grade silver in the South Lorrain field, and has the unique feature that its comparatively large production came entirely from the Nipissing diabase and from a depth of from 100 feet to 250 feet below the Keewatin contact.

It is essentially a "one-vein" mine, though a branch of the main vein produced ore for a length of 150 feet and a depth of 60 feet.

The main vein runs in width from a fracture up to six inches, and is usually accompanied by two or more parallel fractures from a few inches to two feet away on either or both sides. The strike is northeast-southwest, and the dip is practically vertical.

The channel of mineralization would appear to be a minor reverse fault, striking approximately north and south and dipping to the west at about 20° . At the fourth or 230-ft. level the vein is displaced by a throw of 15 feet. The silver-bearing solutions circulated upward from this fault for a distance of 100 to 150 feet. A few patches of ore were found below the fault, but not more than a maximum of 45 feet below.

In the plane of the vein the ore-shoots rake to the southwest at from 15° to 30° , more or less, conforming with the dip of the contact between the diabase and the overlying Keewatin. At the shaft the contact was, before erosion, about 100 feet above the collar; and high-grade was found in the outcropping of the vein at the shaft. At the southwest corner of the property, 500 feet distant along the strike of the vein, the contact is about 100 feet above the top of the ore zone. This is an interesting feature, and shows a relation between ore zone and contact similar to many cases in Cobalt where the ore zones in the conglomerate of the Cobalt series conform to the Keewatin contact at a more or less regular distance from it.

After the vein leaves the Wettlaufer ground, at the southwest corner, it crosses the northwest corner of the Silver Eagle property, H.R. 97, a length of 20 feet on the fourth, or 230-ft. level, and "feathers" out on the Curry or Pittsburg Lorrain Syndicate property, H.R. 105, in a further fifty feet. Considerable high-grade was taken out of the Silver Eagle, but no ore was found on the H.R. 105 property for more than 20 feet southwest of the line. Northeast of the shaft the vein continues, from two inches to four inches in width, for a further 500 feet, where it weakens, splits into fractures and practically dies out. No ore was found for more than 80 feet beyond the shaft in a northeast direction.

It might be added that the diabase in the vicinity of the vein shows little jointing or fracturing. Consequently, leaf silver penetrated only a few inches into the wall rock, and the quantity of mill-rock from the walls was negligible.

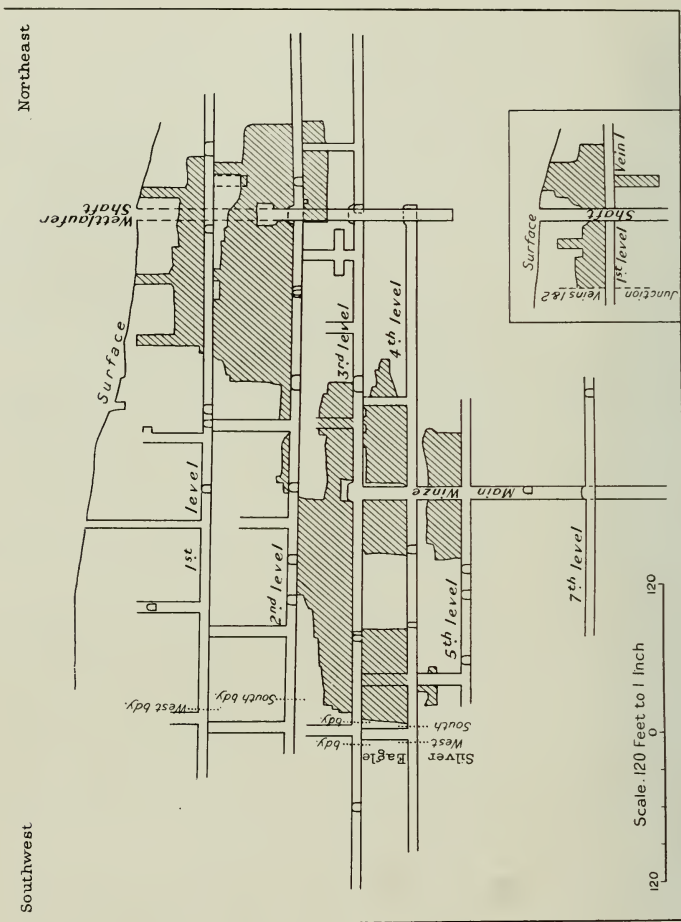


Fig. 54—Stope section of Wettlaufer vein. Furnished by Mr. Horace F. Strong.

Mr. Strong has also very kindly furnished the writer with a stope section of the vein, and with plans of the various levels (Figs. 54 and 53).

A. G. Burrows, who examined the area in 1908 for the Ontario Bureau of Mines, has this to say about the Wettlaufer:—

On the Wettlaufer claim, H.R. 85, there were found three parallel veins with a strike north-east and southwest. Of these, the two northerly veins had rich shoots showing native silver in sheet form, while the south vein carried smaltite with low silver values. The veins were narrow, but parts of them attained a width of six inches. Flake silver is shot into the diabase wall rock from one to three inches. The distance from the north to south vein is about ninety feet.¹

¹Annual Report, Ont. Bur. Mines, Vol. XIX, 1913, pt. II, p. 141.

The Ontario Department of Mines is also indebted to J. B. Tyrrell for information concerning the dip of the top of the Nipissing diabase sill in the mine workings of the Wettlaufer. The information was conveyed in the following personal letter to the writer:—

At that time (1913) five levels had been driven, though I have not a definite record of the depths of the levels, except that the first one was 65 feet below the collar of the shaft. This level was driven westward to the contact of the diabase and Keewatin, and on it the contact was 30 feet farther west than at the surface, making it dip westward at an angle of 64°. The other levels had not reached the plane of this 64° slope or the contact, so that my determination of the slope was taken from these two points.

The inspectors of mines for Ontario have published from time to time the following information concerning the Wettlaufer:—

In 1908 the following work was accomplished: This claim, H.R. 85, adjoins the Keeley to the southeast. Most of the claim is in diabase, and the vein found runs about at right angles to the contact of the diabase with the Keewatin, and in a northeast and southwest direction. The vein or fissure has been stripped for a considerable distance, and some test pits have been sunk on it. The vein opens up in lenses in places three to four inches in width, carrying good values in silver. A company has been formed known as the Wettlaufer Lorrain Silver Mines, Limited, of which Mr. Wettlaufer is president, Mr. F. C. Loring, managing engineer, and Mr. A. C. Bailey, superintendent.¹

In 1909 work was done as follows:—

The Wettlaufer mine is the largest producer in South Lorrain. The main shaft is 150 feet deep, with first level at 65 feet and second level at 140 feet. On the first level, on No. 1 vein, drifts have been run south 190 feet. No. 2 vein is cut by a crosscut from the shaft 79 feet in length. On this vein some 200 feet of drifting has been done. It joins No. 1 vein about 100 feet southwest from the shaft. On the second level the drift southwest from the shaft is 300 feet in length and is driven northeast 175 feet. At a point 75 feet southwest of the shaft a winze is being sunk having a depth at date of inspection of 32 feet. No stoping of any amount has been done.²

Regarding operations for the year 1911, the Inspector of Mines reported as follows:—

The Wettlaufer is the largest and hitherto the only steady producer in South Lorrain. It is owned and operated by the Wettlaufer Lorrain Silver Mines, Limited, which have an authorized capital of 1,500,000 shares of a par value of \$1.00, and have paid \$450,000 in dividends to June 1st, 1912. On the advent of electric power to the camp from the British Canadian Power Company, a new plant was installed, consisting of a 12-drill compressor, driven by a 200-h. p. motor. A 30-ton concentrating mill has been erected. The main shaft has been sunk to the fourth level, a depth of 250 feet. Levels have been run at depths of 65 feet, 140 feet, 185 feet, and 250 feet. The vein has been developed for a length of 500 feet, the drifts on each level having been run approximately this distance. A winze was sunk at a point 210 feet southwest of the shaft from the fourth to the fifth level, and a drift runs south 160 feet and north 70 feet.³

According to the Inspector of Mines, operations carried on in 1912 were the following:—

The Wettlaufer was the only shipper in South Lorrain during 1912. It is owned and operated by the Wettlaufer Lorrain Silver Mines, Limited. The main shaft has been sunk to the fourth level, a depth of 250 feet. At a point 210 feet southwest of the shaft a winze has been sunk to the seventh level a total depth from the surface of about 500 feet. On the fifth level drifts have been run northeast and southwest of the winze, distances of 70 and 180 feet, and on the seventh level 120 feet and 130 feet respectively. The mill has a capacity of about 30 tons a day.⁴

In 1913, the Wettlaufer operated until October 31st, when it was decided to cease active work at the property. During the year \$141,659 were paid in dividends. Some 1,390 feet of drifts, crosscuts, raises, and winzes were run.⁵

¹Annual Report, Ont. Bur. Mines, Vol. XVIII, pt. I, 1909, pp. 124-125.

²Vol. XIX, pt. I, 1910, pp. 114-115.

³Vol. XXI, pt. I, 1912, p. 147.

⁴Vol. XXII, pt. I, 1913, p. 123.

⁵Vol. XXIII, pt. I, 1914, p. 157.

In 1916, the Inspector of Mines reported as follows regarding the Wettlaufer:—

The Comfort Mining and Leasing Company operated the Wettlaufer property under lease from the Wettlaufer Lorrain Mining Company. Work during the year was confined to milling of fines in the dump and jig tailings from previous milling operations. The tailings were hoisted on an incline and dumped into a raise near the mill, and trammed to the shaft on the 50-ft. level. Work was discontinued during the year.¹

In August, 1917, the Pittsburgh-Lorrain Syndicate acquired the Wettlaufer mine and mill under lease, and during the autumn of 1917 the Wettlaufer dump was milled. About 750 feet of drifting and crosscutting was done on the third and fourth level, but no new veins were discovered.²

In 1918, the Pittsburgh-Lorrain Syndicate operated the Curry and Wettlaufer mines until November 30th, 1918, when work was suspended at both properties. The surface dumps were worked over and a considerable amount of mill-rock was obtained from the underground workings.³

In June, 1919, the Pittsburgh-Lorrain Syndicate began to re-treat sand and tailings at the Wettlaufer mill and were handling 20 to 30 tons daily during the autumn. Two small shipments of concentrates were made.⁴

Curry Claim, H.R. 105

The Curry claim is contiguous to the Wettlaufer on the southwest. It was not working at the time it was visited and the mine workings were not accessible. Considerable underground work has been done on the property from an inclined shaft. The Inspector of Mines gives an account of the underground work accomplished, and Horace F. Strong makes reference to the vein and mining operations in his report on the Wettlaufer mine on page 225 of this report. It would appear that the Wettlaufer vein extended about 50 feet into the Curry and then "feathered" out; about 20 feet of the vein on the Curry is reported to have yielded some ore.

On the dump there are pieces of vein matter, showing eight to eleven inches of almost pure smaltite.

About 300 yards southwest of the inclined shaft, there is another shaft sunk in Keewatin rocks. On the dump from this shaft there are pieces of vein matter consisting of fine-grained, banded calcite, or dolomite. The dump also has blocks of diabase, but most of the dump consists of Keewatin basalt.

The following information from the annual reports of the Inspector of Mines is reprinted below.

In reference to operations in 1912 on the Curry, H.R. 105, the Inspector of Mines reported:—

On H.R. 105, adjoining the Wettlaufer on the southwest, the Pittsburgh-Lorrain Syndicate have been engaged in development work under consulting engineer, J. A. Rice. An inclined shaft has been sunk 271 feet, and a crosscut driven 45 feet to connect with the Wettlaufer workings.⁵

The Inspector of Mines, referring to operations in 1914, reported:—

The Pittsburgh-Lorrain Syndicate operated this property adjoining the Wettlaufer mine during the year, with a force of 15 to 25 men. The workings consist of a shaft of which the first 200 feet is an incline of about 45° and the next 200 feet is vertical, about 330 feet of raises and winzes and 1,650 feet of drifts and crosscuts. This represents the work done up to November 1st, 1914, in the two years the property has been working.⁶

¹Annual Report, Ont. Bur. Mines, Vol. XXVI, 1917, p. 132.

²“ “ “ “ “ Vol. XXVII, pt. I, 1918, p. 131.

³“ “ “ “ “ Vol. XXVIII, pt. I, 1919, p. 153.

⁴“ “ “ “ “ Vol. XXIX, pt. I, 1920, p. 110.

⁵“ “ “ “ “ Vol. XXII, pt. I, 1913, p. 123.

⁶“ “ “ “ “ Vol. XXIV, pt. I, 1915, p. 129.

The property was worked continuously in 1915 by the Pittsburgh-Lorrain Syndicate. The Inspector of Mines' report was as follows:—

The shaft has been sunk 275 feet on the slope, the first 175 feet is at 45° and the remaining 100 feet 85°. On the fourth or 175-ft. level a winze was started about 500 feet southeast of the main shaft and was sunk for 115 feet at 80°. Levels were opened off the winze at 50 and 100 feet, and by February, 1916, the drifting done on these winze levels was: on the 50-ft., 50 feet to the northwest and 50 feet to the southeast; on the 100-ft., 20 feet to the northwest and 75 feet to the southeast. A No. 1½ special Sirocco reversible fan is used for ventilating the winze workings. Just above the winze a body of high-grade ore was encountered. The shoot is about 60 feet long; and north of the winze it extends to a known height of 85 feet above this level, while south of the winze it runs for 40 feet above. It is in the Keewatin series just above the Keewatin-diabase contact.¹

In 1916, the Pittsburgh-Lorrain Syndicate worked the Curry mine continuously during the year. The Inspector of Mines reported as follows:—

The shaft in the main workings is now 400 feet deep, and work during the year consisted of drifting on the fifth level and raising on the fourth. The winze workings from the fourth level were abandoned. Shaft No. 2 is 110 feet deep, and 500 feet of drifting in the direction of No. 1 shaft was done during the year.²

In 1917, the following work at the property was done:—

Development of the Curry mine, in South Lorrain, was continued during 1917 by the Pittsburgh-Lorrain Syndicate. Some high-grade ore was stoped on the fourth level. In August, 1917, the syndicate acquired the Wettlaufer mine and mill under lease. Operations at the Curry were suspended, and during the autumn of 1917 the Wettlaufer dump was milled. At the Wettlaufer about 750 feet of drifting and crosscutting were done on the third and fourth levels, but no new veins were discovered. Underground work at the Curry mine was resumed and the mill has since been treating Curry ore.³

In 1918, the Pittsburgh-Lorrain Syndicate operated the Curry until November 30th, 1918, when work was suspended.⁴

Silver Eagle Claim, H.R. 97

The Silver Eagle is contiguous on the south to the Wettlaufer. Horace F. Strong states that the Wettlaufer vein crossed the northwest corner of the Silver Eagle and that some high-grade ore was mined from this part of the Silver Eagle claim (see report on Wettlaufer by Strong, on page 225 of this report). The claim produced 7,989 ounces of silver in 1918.

Bellellen Claim, R.L. 470

The Bellellen is contiguous to the Little Keeley on the east. It was formerly known as the Newman. The property has produced 31,630 ounces of silver.

It was not pumped out at the time of examination in October, 1922. On the surface most of the rock is Keewatin basalt, but the Nipissing diabase sill is exposed on the southwest part of the claim. The diabase probably dips below the Keewatin, judging from the structure at the Keeley and Frontier mines.

On the dump from the main shaft there are blocks of vein material, showing the vein to have a width of 12 to 15 inches of white calcite. Both smaltite and chloanthite are found in these blocks. The presence of chloanthite was determined by W. K. McNeill, Provincial Assayer. On the dump are blocks of micamphrophyre and feldspar-porphry.

The following information regarding the underground workings is reprinted from the reports of the Inspector of Mines.

¹Annual Report, Ont. Bur. Mines, Vol. XXV, pt. I, 1916, p. 126.

²Vol. XXVI, 1917, p. 132.

³“ “ “ “ “ Vol. XXVII, pt. I, 1918, p. 131.

⁴“ “ “ “ “ Vol. XXVIII, pt. I, 1919, p. 153.

Referring to the year 1909, the following work was done:—

Considerable trenching had formerly been done on this claim. The present owners, under the direction of Norman R. Fisher, have sunk a shaft 75 feet and drifted 100 feet.¹

In 1911, the following work was done:—

No. 1 shaft is 80 feet deep, with 144 feet and 114 feet of drifting north and south of the shaft on the 80-ft. level: some stoping has been done. No. 2 shaft is 100 feet deep, with 200 feet of drifting and crosscutting at the 100-ft. level.²

In 1912, work was done as follows:—

On R.L. 470 the Bellellen Silver Mines, Limited, have been engaged part of the year in carrying on development work. All work is confined to No. 2 shaft, which is 100 feet deep with drifts west 56 feet and south 120 feet. A winze 35 feet deep has been sunk from the south drift, and a drift started north from the bottom of this winze.³

In September, 1915, work was resumed on the Bellellen:—

On the 100-ft. level, about 100 feet north of No. 2 shaft, a winze has been sunk 75 feet. On the 40-ft. level of this winze 30 feet of drifting has been done, and at the bottom of the winze a drift extends to the south a distance of 125 feet.⁴

Regarding work accomplished in 1916, it is reported that work was carried on continuously during the year:—

The winze on the 100-ft. level, about 100 feet south of No. 2 shaft, was down 145 feet when inspected in November, 1916. About 75 feet of drifting was done at the bottom level. Shaft No. 1 is 70 feet deep with drifts to north and south at the bottom level. Work during the year was confined to No. 1 shaft.⁵

In 1917, work was continued most of the year:—

The winze on the 100-ft. level was sunk to a depth of 275 feet, and at the 200-ft. winze level a drift was run to the south, a distance of 100 feet.⁶

Maidens Claims, H.R. 69, H.R. 70, H.R. 67, H.R. 66

The Maidens claims are less than half a mile west of Lake Timiskaming. The property was not being worked in the fall of 1922.

There are two shafts about 100 yards apart, and two adits; most of the work has been done on H.R. 69.

On the dump of the most easterly shaft leaf silver was noted; and there were also noted thin films of a black mineral which W. K. McNeill determined to be a sulphantimonide of silver, but the quantity of the mineral obtained was too small for the determination to be absolutely definite. Pieces of the vein on the dump show a width of six to eight inches of calcite and a little quartz. The vein also carries some smaltite. Some of the blocks of vein matter show rock fragments cemented with calcite, suggesting a fault vein; a little cobalt bloom was noted in this fault breccia, and some pure smaltite. Judging from the rock seen on the dump the Nipissing diabase was not encountered in the workings. Blocks of lamprophyre were found on the dump.

The dump from the east adit shows a calcite vein which is over a foot wide in places.

¹Annual Report, Ont. Bur. Mines, Vol. XIX, 1910, pt. I, p. 113-114.

²“ “ “ “ “ Vol. XXI, 1912, pt. I, p. 147.

³“ “ “ “ “ Vol. XXII, 1913, pt. I, p. 123.

⁴“ “ “ “ “ Vol. XXV, 1916, pt. I, p. 125.

⁵“ “ “ “ “ Vol. XXVI, 1917, pt. I, p. 132.

⁶“ “ “ “ “ Vol. XXVII, 1918, pt. I, p. 131.

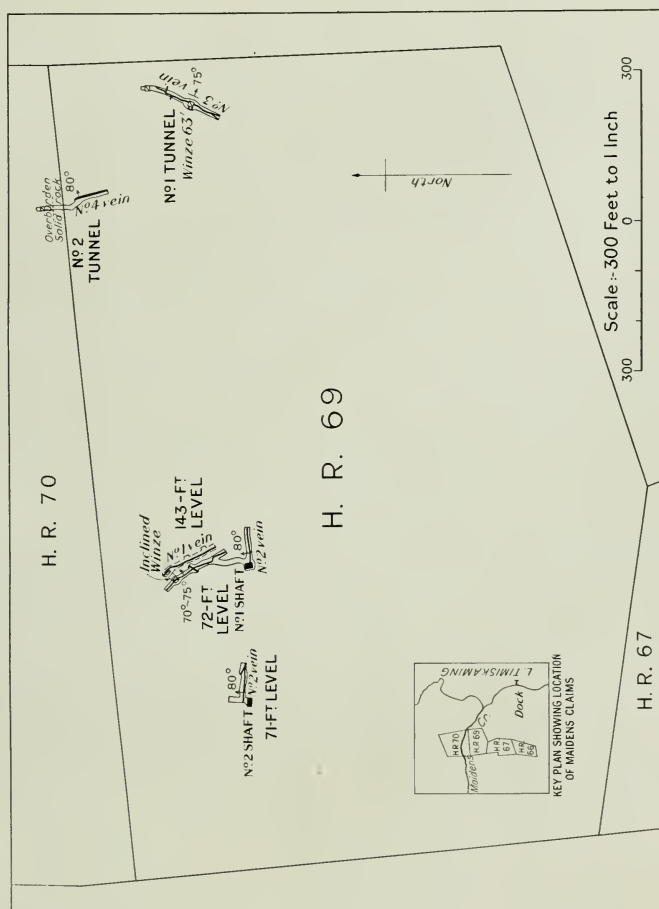


Fig. 55—Plan showing mine workings of Maidens claim, H.R. 69.
Furnished by Dr. J. Mackintosh Bell.

On the southeast corner of H.R. 69 the Nipissing diabase is exposed. The rest of the claim is underlaid by Keewatin basalt, although much of the Keewatin is heavily covered with drift. The contact between the Nipissing diabase and Keewatin is drift-covered, so that it is not known whether the Nipissing diabase dips below the Keewatin. It is important to determine how the diabase dips, so that some idea may be obtained as to how far the top of the diabase sill is below the surface in the vicinity of the veins. At the Keeley, Frontier, and Wettlaufer mines, most of the ore has been obtained along the contact, within 100 or 200 feet above or below.

The nearest contact of the Nipissing diabase and the Keewatin is about one mile westward from the Maidens on claims R.L. 461 and H.S. 11. Here the

contact is vertical. The contact is also vertical about half a mile to the north-west on claim B.C. 105.

Thus, all that can be said is that the nearest exposed contacts to the Maidens claims are vertical. Diamond-drilling or shaft-sinking will alone determine the dip of the diabase sill on the Maidens claims.

The Keewatin is cut in one place by a hornblende diabase intrusion; it has the appearance of a dike of Haileyburian age.

As the mine workings were not accessible at the time the claims were visited, an examination was not made. The writer is indebted to J. Mackintosh Bell for the following description and accompanying plan (Fig. 55) of the property:—

Two vertical shafts have been sunk on the property, and two tunnels driven from the surface in the valley of Maidens creek. No. 1 shaft which, including a sump, is 80 feet deep, communicates with a level at 72 feet, from which a winze sunk on the dip of No. 1 vein provides entry to a sub-level 71 feet vertically below. There is an 8-foot sump at the bottom of the winze. Three hundred feet of drifting and crosscutting have been done in the main level, and 125 feet in the sub-level.

No. 2 shaft is 85 feet deep, and 91 feet of crosscutting and drifting have been done from a level of 71 feet. The shaft was commenced on No. 2 vein, which, however, is carried by its northerly dip out of the workings.

No. 1 tunnel driven on No. 3 vein is 162 feet long, and from it a winze reported to be 63 feet deep has been sunk.

No. 2 tunnel, 160 feet long, is a crosscut for 100 feet from the adit, and for the remainder of the distance, 60 feet, is driven on the course of No. 4 vein. The entrance of this tunnel, approximately 40 feet above Lake Timiskaming, has been taken as the datum level. The entrance of No. 1 tunnel is 1.7 feet higher; the collar of No. 1 shaft, 147.6 feet; and the collar of No. 2 shaft, 153.7 feet.

Four strong veins have been so far discovered on the property, all of which have been opened up to a small extent by the developments previously described. In addition, a large number of minor veins have been located in the sub-surface workings, branching from the principal veins.

No. 1 vein, which dips at an angle of about 75° to the northeast, has been opened up for 145 feet in the No. 1 level of No. 1 shaft and for 120 feet in the No. 2 level thereof. The vein, which consists principally of shattered country rock and calcite, contains in places considerable amounts of smaltite and some native silver. It is noteworthy that the silver values which are found both in the vein and the adjoining country rock occur over a greater length and are in general higher at the second than at the first level. The shoot of silver-bearing material has a length of 15 feet at the first level, which assays as follows:—

10 feet from north face.....	11 ounces over 48 inches
15 " " " "	8 " " 54 "
20 " " " "	56 " " 25 "

At the second level, irregular values show for a length of 65 feet, measuring southward from the north wall of the sump, as follows:—

North wall of sump.....	12 inches	52.8 ounces
10 feet.....	18 "	5.2 "
15 "	30 "	1.6 "
20 "	16 "	1.8 "
25 "	38 "	.8 "
30 "	4 "	12.2 "
35 "	48 "	1.0 "
40 "	16 "	28.0 "
45 "	26 "	79.0 "
50 "	49 "	.2 "
55 "	18 "	.4 "
60 "	31 "	18.4 "
65 "	21 "	.4 "

No. 2 vein, where it has been developed both in No. 1 and No. 2 shafts (85 feet in the former and 78 feet in the latter) consists almost entirely of soft, highly fractured country rock containing in places some calcite and generally much pyrite. The vein occupies what is clearly a pronounced fault fracture. The strike is easterly, and the dip varies from high angles northerly to high angles southerly, but is generally the former. Wire silver is reported to have been found in the soft vuggy material contained in the vein in the portion now hidden by the shaft timbers.

No. 3 vein is a particularly strong deposit of pink calcite commonly 18 inches or near in width, and containing in many places considerable smaltite. The silver values are low in the portion so far developed. The vein strikes northeasterly and dips 75° to the southeast.

No. 4 vein resembles No. 3 in mineralogical character, but in general it appears to be somewhat weaker. It strikes a little west of north and dips at 80° to the easterly.

In 1913, A. G. Burrows described the Maidens claim in the following words:—

On H.R. 69, Maidens claim, there has been extensive development work. Near the east side-line a tunnel has been driven from the base of a hill a distance of 285 feet on a calcite vein [No. 3]. At 100 feet a winze has been sunk to a depth of 60 feet. The vein in places has a width of 12 inches. Smaltite and niccolite are found in bunches in the vein. Low silver values are reported to have been obtained on assay. On vein No. 4 to the northwest a tunnel has been driven 225 feet. The vein filling is chiefly calcite with smaltite and niccolite in portions of the vein, 5 to 7 inches in width. The veins are in Keewatin, just north of the contact with the Nipissing diabase, and strike a little east of north.¹

The inspectors of mines for the Province of Ontario have given in their departmental reports the following information regarding the Maidens claims. In 1908, the work done was as follows:—

On mining claim H.R. 69, which lies about one mile northwest of the new government dock, the company are doing mining work south of the government road, consisting of adits driven south into the hill, which has an elevation of over 100 feet above the road. No. 1 adit was driven 63 feet through clay to the rock and 135 feet farther, part of it being on the vein which was encountered. Another adit has been begun 300 feet west of the No. 1 and has been driven 50 feet through clay to the rock.²

In 1909, the two adits were driven farther into the hill.

In addition to trenching and test pitting, two adits have been driven, No. 1 having a length of 285 feet and No. 2, 225 feet.³

For the year 1914, the report on the property is as follows:—

The Maidens Silver Mining Company was operating its property during most of the year with a force of six men. A winze was being put down in November about 200 feet from the shaft and had reached a depth of 60 feet below the 75-ft. level. There is another shaft of the same depth, 85 feet, which was not working.⁴

Little Keeley Claim, H.S. 40

The Little Keeley is north of the Frontier. The property was flooded at the time of examination in the fall of 1922. Little underground work has, however, been done, and the records of the Department do not give an account of this work. The rocks on the surface are almost wholly Keewatin basalt.

The property has been acquired by the Mining Corporation of Canada, Limited.

Lorrain Consolidated Claim, H.R. 24

The Lorrain Consolidated, formerly known as the Harris, was not working and was flooded in the fall of 1922. The property is contiguous to the Frontier on the east. A shaft has been sunk to a depth of 263 feet, and 800 feet of drifting and crosscutting done on the bottom level.

On the dump are rocks consisting of Keewatin basalt and of Nipissing diabase. The shaft was begun in Keewatin, and evidently the shaft or other workings passed through this formation into the Nipissing diabase.

Judging from the dump, the workings followed a strong vein; blocks on the dump show the vein to be as wide as one foot, and to contain almost pure smaltite and niccolite six inches wide in places.

The vein has been exposed on the surface by some deep trenches; these have partly fallen in. Where the vein is now seen in the trench, it is from three to six inches in width, consisting of calcite with some pure smaltite and niccolite.

¹Annual Report, Ont. Bur. Mines, Vol. XIX, pt. II, 1913, p. 143.

²“ “ “ “ “ “ Vol. XXIII, pt. I, 1909, p. 124.

³“ “ “ “ “ “ Vol. XIX, pt. I, 1910, p. 114.

⁴“ “ “ “ “ “ Vol. XXIV, pt. I, 1915, p. 130.

Regarding the work done in 1908, the Inspector of Mines made the following remarks:—

This claim lying to the east of and adjoining the Haileybury Silver Mining Company property is owned by Mr. Mark Harris. Captain Terrill is in charge of this work and has sunk two pits to a depth of 22 feet and 18 feet respectively.¹

The work done during the year 1916 is thus summarized by the Inspector of Mines:—

The Lorrain Consolidated Mining Company, formerly known as the Harris, continued development work at its property in South Lorrain during the year (1916). Work was in charge of J. G. Harkness, on contract; the shaft was sunk to a depth of 263 feet, and about 800 feet of drifting and crosscutting done on the bottom level. It closed down on June 15th, 1917.²

Montrose, H.R. 459

The Montrose, R.L. 459, joins the Keeley on the east. A shaft has been sunk to a depth of 110 feet in the Nipissing diabase.³ On the dump there is a vein of brown weathering calcite or dolomite evidently carrying some ferrous iron.

T.C. 71

Regarding this claim, T.C. 71, A. G. Burrows reported in 1913:—

On T.C. 71, east of Loon lake, a tunnel has been driven 100 feet on a strong calcite vein about a foot in width.⁴

Taylor Claim, R.L. 471

The Taylor claim adjoins the Bellellen on the north. A. G. Burrows reported in 1913:—

On R.L. 471, near the east side line, there is a strong vein of massive smaltite, on which a shaft has been sunk 65 feet. The vein is in the Keewatin.⁵

Alice Lorrain Claim, R.L. 467

The claim is about one-quarter of a mile north of the Bellellen.

The Inspector of Mines reported in 1912 that a shaft had been sunk on the property to a depth of 75 feet.⁶ This shaft is in the Nipissing diabase sill at a point about 100 yards east of the contact between the Keewatin and Nipissing diabase. The diabase is the acid variety containing pink spots which consist of a micrographic intergrowth of quartz and pink feldspar. About 125 yards southwest of the shaft, the contact between the Keewatin and diabase is exposed for 40 feet, and the contact may be seen to dip steeply westward.

On the dump, there are pieces of a calcite vein one to six inches wide.

A plant had been erected, but has since been burnt.

Forneri Claim, H.S. 42

The Forneri claim adjoins the Little Keeley on the north, and has been acquired by the Mining Corporation of Canada. It is almost entirely underlain with rocks of the Cobalt series, except at the south end where the Keewatin series outcrops. A specimen from a vein on this claim was submitted to W. K. McNeill, Provincial Assayer, who found that the sample was cobaltite. This vein may be the northward extension of Wood's vein, though this has not been proven as yet.

¹Annual Report, Ont. Bur. Mines, Vol. XVIII, pt. I, 1909, p. 123.

²“ “ “ “ “ Vol. XXVI, 1917, p. 133.

³“ “ “ “ “ Vol. XXI, pt. I, 1912, p. 147.

⁴“ “ “ “ “ Vol. XIX, pt. II, 1913, p. 143.

⁵“ “ “ “ “ Vol. XIX, pt. II, 1913, p. 143.

⁶“ “ “ “ “ Vol. XXI, pt. I, 1912, p. 147.

A. G. Burrows in 1913 reported on this claim as follows:—

On H.S. 42 (Forneri claim) there is a vein about three inches in width, with strike north-northeast, and occurring in conglomerate. The vein material is smaltite and copper pyrites in calcite and quartz. A surface sample on assay showed no silver values. A shaft has been sunk to a depth of 75 feet. At 35 feet the vein dipped from the shaft. It is reported that silver values were obtained on assay at 14 feet depth.¹

Sharp Lake Claim, B.C. 100

For the year 1911, the Inspector of Mines reports as follows regarding this claim, which is a mile north of the Forneri:—

On claim B.C. 100 the Sharp Lake Mines, Limited, have sunk a shaft a depth of 50 feet. At the 50-ft. level a drift has been run south 145 feet and east 60 feet.²

H.R. 63

On H.R. 63, on the shore of Lake Timiskaming near Maidens creek, a tunnel has been driven 300 feet into the Nipissing diabase at the foot of a high cliff. The tunnel strikes west 35° south, and was driven to intersect a narrow calcite vein, striking west 32° north, which outcrops about 100 yards south of the portal of the tunnel. The tunnel apparently was not run far enough to reach the vein; at any rate the vein was not encountered. The vein occurs in a joint plane of the diabase along which some horizontal shearing has taken place. The vein is rusty in places. At the end of the tunnel, there is a pink calcite vein from one-quarter of an inch to an inch in width. A horizontal fault, with a little calcite in it, was noted in the tunnel. At the tunnel portal, there is a diabase dike cutting the Nipissing diabase.

H.R. 14

This claim, H.R. 14, is two claims south of the Maidens claim. A. G. Burrows in 1913 reported as follows concerning it:—

On H.R. 14, near the west side line, some native silver has been obtained in a narrow vein in the diabase.³

Tallen Claim, H.R. 106

The Tallen claim is at the northeast corner of Trout lake. The following information concerning the property has been published by the Inspector of Mines:—

Mr. J. D. Dodd has a contract for sinking a shaft on the property of the Tallen Mining Company, Limited, half a mile southwest of the Curry, in the latter half of the year. Work was started in a prospect shaft 60 feet deep, from the bottom of which 120 feet of drifting had been done. This shaft had a depth of 180 feet on March 1st, 1915.⁴

Regarding operations for the year 1915 and early in 1916, the Inspector of Mines stated:—

On claim H.R. 106, South Lorrain, the Tallen Mining Company, Limited, has sunk a two-compartment shaft 200 feet.

On the 200-ft. level a drift is being run north 40° west. In February, 1916, the face of this drift was 200 feet from the shaft. Eight men are employed. All the work done in this shaft is in diabase, with the exception of the last 20 feet at the face of the above mentioned drift, which is in Keewatin.⁵

¹Annual Report, Ont. Bur. Mines, Vol. XIX, pt II, 1913, p. 143.

²“ “ “ “ “ Vol. XXI, pt. I, 1912, p. 147.

³“ “ “ “ “ Vol. XIX, pt. II, 1913, p. 143.

⁴“ “ “ “ “ Vol. XXIV, pt. I, 1915, p. 130.

⁵“ “ “ “ “ Vol. XXV, pt. I, 1916, p. 126.

A. G. Burrows in 1913 remarked:—

On H.R. 106, adjoining Trout lake on the northeast, a five by seven shaft has been sunk 50 feet on a calcite vein carrying smaltite.¹

King George Claims, H.R. 110, H.R. 170

These two claims are at the northeast corner of Trout lake, and are mostly in the bed of this lake.

For the year 1911, the Inspector of Mines reports as follows on the claims:—

Active development work was carried on during 1911 on claims H.R. 110 and H.R. 170. The main shaft has been sunk to a depth of 272 feet, with 30 feet of crosscutting at the 250-ft. level.²

T.C. 73

Claim No. T.C. 73 is about one-quarter of a mile east of Trout lake. In 1913, Mr. A. G. Burrows reported as follows on this claim:—

On T.C. 73 there is a shaft down 40 feet on a calcite vein with disseminated smaltite and copper pyrites. These veins have not proved to carry appreciable silver values. The rock is the Nipissing diabase.³

Toronto Lorrain Claim, H.S. 308

At the north end of H.S. 308, near the shore of Lake Timiskaming, there is a calcite vein exposed at the top of the hill which rises up from the shore. The vein is three or four inches wide and strikes westward, dipping steeply to the north. The vein occurs in banded Keewatin basalt, the banding dipping steeply to the north and the vein following about the dip of the banding of the basalt. A little blasting has been done on this vein. Near the foot of the hill, there is a shaft reported to be about 30 feet deep, following a small calcite vein and an aplite dike. This shaft is in coarse-grained Nipissing diabase. It is some 60 or 70 feet below the vein at the top of the cliff. Further work will show whether these two veins join. The contact between the diabase and the overlying Keewatin is covered on the hillside above the shaft, but is exposed a short distance to the north, where it dips 25° to 30° to the southwestward.

In January, 1923, the Toronto Lorrain Silver Mines, Limited, was organized to take over this claim, together with mining claim No. 19247, surveyed as H.F. 9, and mining claim No. 19389, surveyed as H.R. 123. The president and general manager of the company is Walter J. D. Penly.

H.S. 500

This claim is about one-quarter of a mile southeast of Oxbow lake.

There is a shaft on the property reported to be 38 feet deep in the Keewatin. On the dump beside the shaft, there is a calcite vein about half an inch in width. The shaft is 400 or 500 feet south of the Nipissing diabase. The diabase contact is exposed on the hillside, dipping 37° to 40° southeastward. Some unusually deep trenches have been made on the claim.

H.R. 56

On H.R. 56, which is about one-quarter of a mile south of Loon lake, there is a shaft reported to be about 40 feet deep. The shaft is in Keewatin, and is 100 feet east of the west boundary. There is a vein of calcite an inch or two wide, in places six inches wide.

¹Annual Report, Ont. Bur. Mines, Vol. XIX, pt. II, 1913, p. 143.

²" " " " " Vol. XXI, pt. I, 1912, p. 147.

³" " " " " Vol. XIX, Part II, 1913, p. 143.

Lang-Caswell

The Lang-Caswell properties, in Lorrain township at the northeast corner of lot 8, in the first concession, were not examined. There is a brief note in the twentieth annual report of the Department which states that:—

Extensive development work was carried on at the Lang-Caswell properties in Lorrain, and while no ore has been shipped, things are said to look very promising.¹

Giroux

On a claim situated on the north shore of Latour lake, concession two, Lorrain township, a shaft has been sunk to a depth of 50 feet and 24 feet of crosscutting done on the 50-ft. level.²

¹Annual Report, Ont. Bur. Mines, Vol. XX, pt. I, 1911, p. 54.

²“ “ “ “ “ “ Vol. XXV, pt. I, 1916, p. 126.



Fig. 56—Old Keeley workings, No. 1 shaft; the original discovery was made in this place.

Lorrain Trout Lake Mines Claim, H.R. 103

In the spring of 1923, this claim was acquired by interests associated with the Mining Corporation of Canada, Limited. Under the direction of this company, work was begun on a shaft which it was planned to sink on the southward extension of Wood's vein. By the end of the year, the shaft had reached a depth of about 350 feet. The results of sampling the vein material in this shaft were published by the Mining Corporation. The assay returns are as follows:—

Channel samples were taken at five foot intervals across the footwall section of the vein. First 35 feet of shaft not on vein.

DEPTH, FEET	INCHES	OUNCES PER TON	DEPTH, FEET	INCHES	OUNCES PER TON
35.....	30.....	8.0	160.....	24.....	29.4
40.....	16.....	15.0	165.....	36.....	22.0
45.....	28.....	6.0	170.....	36.....	22.8
50.....	36.....	65.8	175.....	30.....	23.6
55.....	38.....	260.8	180.....	36.....	44.6
60.....	25.....	132.2	185.....	32.....	11.0
65.....	20.....	72.0	190.....	15.....	22.0
70.....	19.....	2214.0	195.....	12.....	9.2
75.....	18.....	1155.2	200.....	24.....	16.8
80.....	20.....	1017.2	205.....	18.....	77.6
85.....	20.....	133.2	210.....	12.....	198.4
90.....	25.....	54.5	215.....	18.....	36.0
95.....	20.....	.....	220.....	18.....	72.5
100.....	18.....	28.6	225.....	4.....	21.15
105.....	20.....	49.2	230.....	10.....	74.0
110.....	17.....	17.0	235.....	28.....	48.5
115.....	15.....	11.6	240.....	16.....	37.5
120.....	18.....	4.2	245.....	12.....	18.5
125.....	20.....	3.8	250.....	12.....	25.5
135.....	24.....	5.8	255.....	12.....	86.2
140...Timbered.	No sample.	.....	260.....	24.....	3.0
145...Timbered.	No sample.	.....	265.....	20.....	6.0
150.....	54.....	64.8	270.....	21.....	11.0
155.....	48.....	11.6			

AUTHORS' PREFACE TO CHAPTER IV

At the request of Mr. Cyril W. Knight, author of a report on the "Geology and Mine Workings of Cobalt and South Lorrain Silver Areas," the following account has been written of the development of the milling and metallurgical practice in the treatment of the Cobalt silver ores.

For the recovery of silver from these ores, two systems of treatment have been of outstanding importance, namely, gravity concentration, and cyanidation. A third process of relatively minor importance, namely, flotation, was introduced comparatively recently.

The practice used in the different milling plants is largely standardized, although in every mill variations are found in procedure and in the machines used to accomplish a given end. In the following account of the development of the ore-treatment processes, the authors have used the Coniagas mill to illustrate the general practice of gravity concentration and flotation, and the Nipissing mill to illustrate the practice in cyanidation. The practice used in other mills is mentioned, for the most part, only for its historical significance, or because it departs in an interesting and important way from the general practice of the camp.

This plan of development was adopted, after mature consideration, for the following reasons:

(a) The records of these plants were more immediately available and familiar to the authors than were those of similar mills in the camp.

(d) The Coniagas mill is a good example, though no claim is made that it is the best one, of the general standard practice used in gravity concentration and flotation, and well illustrates the various changes and vicissitudes incident to the transition from a high-grade to a low-grade property.

(c) No account is possible of the metallurgy of the Cobalt ores without an extended reference to the work done, and the results achieved, at the Nipissing mills.

(d) This plan of procedure is best adapted to allow of a systematic development of the subject in hand.

In this paper the attempt is made to present a summary of the more important data contained in all previous articles, in addition to much information never before published.

The authors have drawn freely from all printed material on the milling and metallurgical processes of the camp. As far as possible, due acknowledgment for information and data is made by suitable references. A general acknowledgment is here made to cover other cases where a particular reference was not possible.

FRASER D. REID,
J. J. DENNY,
R. H. HUTCHISON.

COBALT, MARCH, 1924.

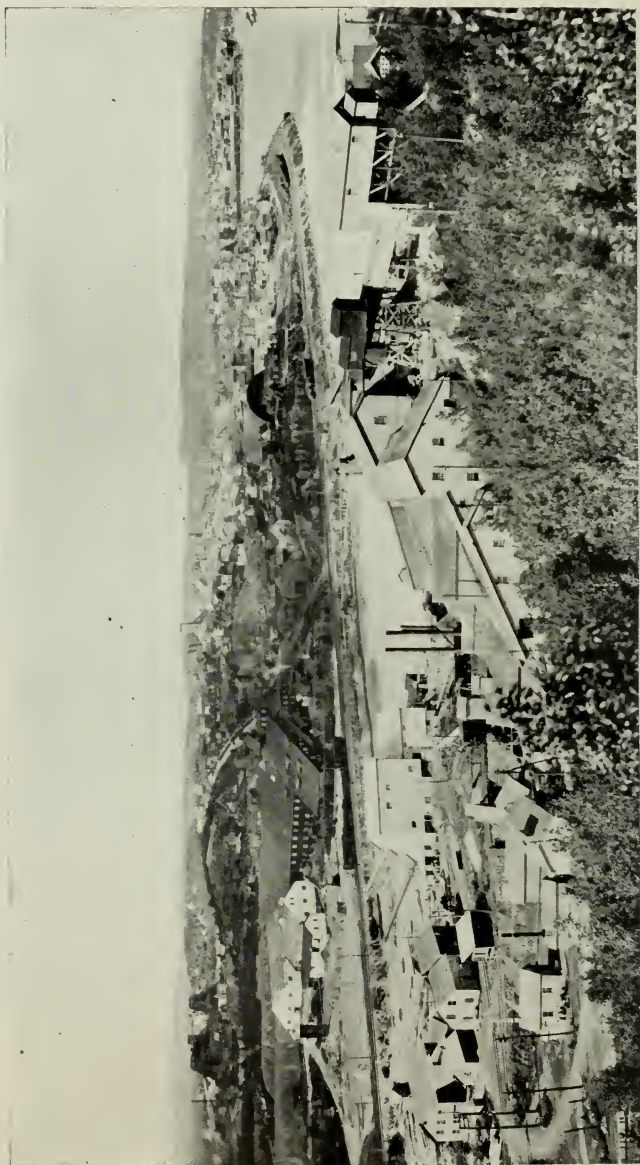


Fig. 57—General view of the town of Cobalt as seen from the hill behind the McKinley-Darragh-Savage mill.

CHAPTER IV

MINING AND METALLURGICAL PRACTICE IN TREATMENT OF SILVER ORES AT COBALT

By

Fraser D. Reid, J. J. Denny, and R. H. Hutchison

SUMMARY OF THE REPORT

The important points in the milling and metallurgical treatment of Cobalt¹ ores are summarized below. These are developed in greater detail in the discussion which follows. (See page 246 *et seq.*)

The Ore

1. The ores of the Cobalt area are a complex assemblage of minerals of which silver, and to a less extent, cobalt and arsenic, are the valuable elements.

2. It is estimated that 97 per cent. of the silver is found in the form of more or less impure native silver. The chief impurity is antimony, together with arsenic and smaller amounts of other elements.

3. The remaining 3 per cent. of the silver is found in various minerals, some of them complex, in which the silver is chemically combined with sulphur, arsenic, antimony, and bismuth. The more important of these minerals are argentite, and the ruby silvers, proustite and pyrargyrite.

4. The valuable minerals have a high specific gravity, and for the most part are readily recovered by standard methods of gravity concentration.

5. The concentrates produced by table concentration and flotation operations are much higher in base-metal sulphides than are the products from jigging and hand-sorting.

6. Gravity concentration will effect a recovery of 80 per cent. of the values from an ore containing 25 ounces of silver to the ton.

7. Early attempts to cyanide the complex ores of Cobalt were unsatisfactory, owing to the heavy consumption of cyanide, the fouling of the working solution, and the prolonged treatment required.

8. The early difficulties were solved by adoption of the practice of fine grinding, by precipitation with aluminium, and later with sodium sulphide, and under some conditions, by a preliminary desulphurizing treatment.

9. Of the various cyanicides present, nickel is the most troublesome in the treatment of high-grade ore and table concentrates. The low-grade wall-rock contains, in addition, sulphides of copper and iron that are cyanide-consuming minerals.

¹The reader will bear in mind that the word "Cobalt" when spelled with a capital "C" refers to the area, not the metal.

10. The cyanidation of high-grade ores and table concentrates requires a preliminary treatment for the removal or oxidation of the various cyanicides present.

11. Flotation concentrates, for the most part, cannot be treated locally by cyanidation, owing to the large amount of base-metal cyanicides present.

12. Processes used to recover the silver from the high-grade ore include the amalgamation-cyanidation treatment, the hypochlorite-cyanidation treatment, and the acid-wash cyanidation treatment.

13. Argentite, the ruby silvers, and pure leaf-silver float readily. Antimonial silver, oxidized ores, and cobalt arsenides are floated with difficulty.

Crushers and Crushing

1. The general practice is to use a Blake or jaw crusher as the primary breaker, followed usually by a medium-size gyratory crusher.

2. The use of the gravity stamp as an intermediate crusher predominates throughout the camp.

3. Fine-grinding is done in tube-mills, the present tendency being to substitute iron balls for flint pebbles.

4. The economic limit of crushing is about 16 mesh for gravity concentration, a minus 80-mesh product for flotation, and minus 200-mesh for cyanidation.

Gravity Concentration—Low-Grade Ore

1. The early practice was to give the ore a preliminary washing treatment by jigging and hand-sorting, to recover portions of high-grade vein-matter broken into the mill-rock.

2. Table concentration is effective on sizes from one-quarter inch to minus 200-mesh sands. The sand tables recover a high-grade concentrate, and discharge a low-grade tailing. The fines are treated or re-treated on slime tables.

3. With the introduction of the flotation process, the preliminary washing treatment was discontinued. Coarser battery screens are used, the battery-discharge is given a roughing treatment on sand tables, and classified, the coarser portion being re-ground in tube-mills, with iron balls. The tube-mill discharge after classification is concentrated on slime tables, the tailing from which goes to the flotation plant.

4. The concentrates from the tables are re-cleaned on a separate table.

5. The middling from the re-cleaning table in some cases is re-ground, but usually is returned in closed circuit to the cleaning table.

Cyanidation

1. Cyanidation was first used as an accessory treatment to recover the values in the slime tailing, the first plant to operate being the Buffalo.

2. Concentration followed by re-grinding and cyanidation was first used at the O'Brien mill, where precipitation with aluminium dust was developed.

3. In the early Nipissing practice, the ore below the stamps was treated by straight cyanidation, after a preliminary desulphurizing treatment. Precipitation was with aluminium dust.

4. Sodium sulphide in 1916 was introduced in place of aluminium as the precipitant.

5. Flotation following cyanidation was not successful.

6. The present Nipissing practice is gravity concentration in cyanide solution, followed by cyanidation after extremely fine grinding.

7. The pulp is agitated for 50 hours in tanks provided with mechanical agitators, in a solution containing 0.25 per cent. KCN, with a dilution of 2.5:1. Aeration is effected by means of 6-inch air-lifts.

8. At the Cobalt Reduction Company, 45 per cent. of the feed to mill is rejected as a 40-mesh and finer sand tailing from table concentration. The remaining 55 per cent. is slime which is treated by cyanidation.

9. Extremely fine grinding is essential to dissolution of the silver values in a reasonable time of treatment.

10. Desulphurization is effective only on ores containing considerable amounts of the complex silver minerals, and is not applicable to the general ore of the camp.

11. The precipitate of silver sulphide is desulphurized with aluminium in a solution of caustic soda. It is then melted and refined in a reverberatory furnace and cast into bars.

12. Sampling of wet concentrates, by coning and quartering, gives accurate results.

Flotation

1. The flotation process was adapted to the treatment of Cobalt ores as a result of the work done at the Buffalo experimental plant.

2. Flotation plays a useful part in the treatment of fines, following gravity concentration.

3. The Callow pneumatic system of flotation is used throughout the camp.

4. The oil mixture in general use is 70 per cent. coal tar creosote, 20 per cent. pine oil, and 10 per cent. coal tar. At the Coniagas plant, in order to treat oxidized minerals, the mixture is sulphidized by distilling the oil, under pressure, with sulphur.

5. Grinding is done to 80 or 100 mesh in tube-mills, or Hardinge mills, using iron balls.

6. The concentrate made by the rougher cells is low in grade, containing about 50 ounces of silver to the ton. This is raised to from 400 to 600 ounces to the ton by re-treatment in re-cleaning cells.

7. The tailing from the cleaner cells is the middling. This is either returned to the rougher cell, or is treated in a separate circuit by flotation or cyanidation.

8. The recovery of undissolved mineral from cyanide tailing by flotation was not successful at the Nipissing mine.

9. The attempt to recover the silver from the flotation concentrate by means of a chloridizing roast in Holt-Dern furnaces, followed by an acid salt-leach or by cyanidation, was not a commercial success.

10. Owing to the high cost of marketing flotation concentrates, the production of a high-grade concentrate is essential.

High-Grade Treatment

1. By the amalgamation-cyanidation treatment, 95 to 96 per cent. of the silver was recovered by amalgamating the ore with mercury in a tube-mill. The remaining 5 to 4 per cent. was recovered by agitating the residue from amalgamation for 36 hours in 0.75 per cent. KCN solution.

2. The amalgam was retorted in oil-fired retorts, and the resulting sponge melted and refined in an oil-fired reverberatory furnace.

3. The Thornhill process was used successfully at the Buffalo mill to recover the mercury from the residues. It consisted of leaching the residues with a solution containing 4 per cent. sodium sulphide, which is a solvent for mercuric sulphide.

4. Various means were tried at the Nipissing plant to recover the mercury volatilized during the retorting and refining processes. These included a system of flues, a bag-house, and the Cottrell system of fume precipitation.



Fig. 58—Kerr Lake mine, view of surface plant and dumps.

5. The processes now used to recover the silver from high-grade ore and table concentrates involve a preliminary treatment for the removal or oxidation of base-metal cyanicides, followed by cyanidation.

6. In the hypochlorite treatment, the ore is ground to 200 mesh in tube-mills, using 2-inch iron balls. Calcium hypochlorite is added to the amount of 50 to 75 lbs. per ton of ore. The tube-mill discharge is classified, and the classifier overflow, after settling and decanting, is filtered on Oliver filters, and washed free of chlorides.

7. In the acid-wash treatment, the pulp, after being ground to 200 mesh, is agitated with a 3 per cent. solution of sulphuric acid at a dilution of 2:1. The pulp is washed several times by dilution and decantation, and lime is added to neutralize the acidity.

8. Cyanidation of the pulp is effected by agitating it for 8 to 14 hours with a solution containing 0.5 per cent. KCN, at a dilution of 20-35:1.

9. Both treatments give a recovery of 98 per cent. of the silver.

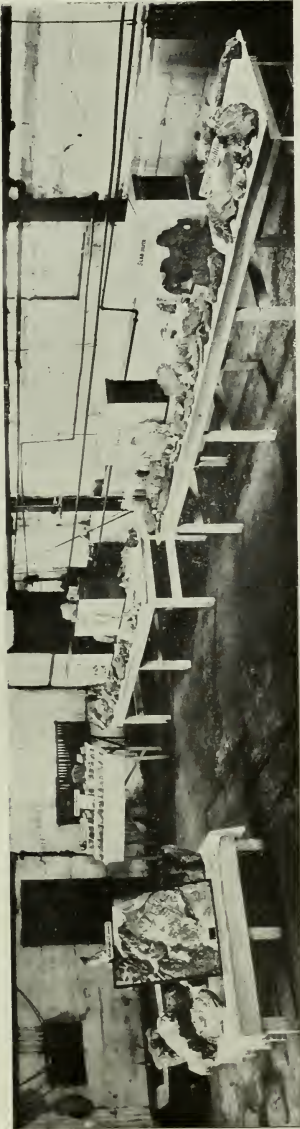


Fig. 59—Minerals of the Cobalt area exhibited at the Nipissing refinery, Cobalt, during the visit of members of the American Institute of Mining and Metallurgical Engineers, August 22 and 23, 1923.

THE SILVER ORES OF COBALT

General Characteristics

The ores of the Cobalt area are remarkable for their high content of silver, and for the complex assemblage of minerals found in the veins and the enclosing wall-rock. The ores include native silver, together with cobalt and nickel, in the form of arsenides, sulphides, sulpharsenides, sulpharsenites, antimonides, sulphantimonides, sulphantimonites, sulphobismuthites, and alteration products. Associated and often intimately mixed with the silver-bearing minerals are found a number of base-metal compounds—smaltite, chloanthite, niccolite, breithauptite, arsenopyrite, cobaltite, native bismuth, millerite, tetrahedrite, chalcopyrite, bornite, emplecite, sphaero-cobaltite, cobalt bloom, annabergite and scorodite, with pyrite, galena, sphalerite, and others. The vein-stones include calcite, together with quartz, dolomite, aragonite, and manganese carbonate. Barite and fluorite occur in the outlying areas.

Silver is, of course, the metal of outstanding economic value, but the cobalt and arsenic and, to a less extent, the nickel, are important by-products. Payment also is made on the copper content of certain shipments. A small amount of gold has been found in some veins, associated with cobaltite and arsenopyrite, and in the decomposed vein-matter.

Of the silver-bearing minerals, native silver is of outstanding importance, as fully 97 per cent. of the values occur in this form. It is found in masses ranging from large slabs to the finest filmy leaf. The native silver of Cobalt is relatively impure, containing only from 85 to 96 per cent. of fine silver. The chief impurity is antimony, together with arsenic and mercury. With increasing antimony content, the native silver grades into dyscrasite. In some veins, the native silver is found in plates and leaf, in a calcite gangue; in other veins, it is found associated and intimately mixed with smaltite, niccolite, and breithauptite.

The remaining 3 per cent. of the silver values is found in the numerous, often complex, silver-bearing minerals, in which it is chemically combined with sulphur, arsenic, antimony, and bismuth. Of these compounds argentite is the most abundant and important, followed by proustite and pyrargyrite, together with small amounts of polybasite, freibergite, freieslebenite, stephanite, matildite, etc. These complex silver minerals seem to occur more abundantly in the Keewatin formation, and in the vicinity of the Cobalt fault. Silver is also found intimately mixed with chalcopyrite and bornite. A few decomposed veins are found, carrying a mud which is high in silver, probably as an alteration product from argentite.

Suitability for Gravity Concentration

The valuable minerals have a high specific gravity and, with certain limitations, are readily recovered by standard methods of concentration, even under conditions that are far from favourable. The general practice has been to give the ore a preliminary treatment in washing-plants before sending it to the stamp bins. For the most part, the high-grade vein-matter separates cleanly from the enclosing wall-rock, and is readily recovered by hand-sorting and jigging. The concentrate from this preliminary treatment is clean high-grade ore.

Ores carrying finely divided silver, in a gangue of smaltite and niccolite,

concentrate readily, and this type of ore predominates in the camp as a whole. A calcite gangue, on account of its low specific gravity, has a buoyant effect, and such material is more difficult to treat. If, as is usually the case, the silver in a calcite gangue is in plates and larger aggregates, it will usually concentrate readily. On the other hand, silver in the form of filmy leaf is difficult to recover by concentration. The gouge, or oxidized material from decomposed veins, is very difficult to treat by concentration, and since it sometimes runs as high as 12,000 ounces of silver to the ton, it will have a very marked effect on the value of the slime tailing.

The veins vary from a mere crack up to 24 inches in width, and at times a strong vein breaks up into a number of stringers. The vein-matter as far as possible is hand-sorted underground; the wall-rock, together with the stringers and unrecovered vein-matter, constitute the milling-rock. After crushing, the vein-matter liberated from the stringers is recovered by the preliminary treatment in the washing-plant. The rejects from this preliminary treatment, which include the wall-rock and calcite vein-matter carrying fine leaf silver, are sent to mill-bins for further crushing and grinding.

The vein-matter, both from different veins and from the same vein, varies widely in silver content. Thus, calcite veins may vary from barren calcite to vein-matter carrying 5,000 ounces of silver to the ton, while smaltite and niccolite veins range from low-grade or barren smaltite and niccolite to material carrying 8,000 ounces of silver to the ton. A similar irregularity in the distribution of the silver content is found in the wall-rock, which may range from low values to more than 75 ounces of silver to the ton. In general, the wall-rock may be said to average from 10 ounces to 16 ounces of silver to the ton, but this may be raised to 40 ounces or higher by the presence of high-grade vein-matter.

In the wall-rock, the silver-bearing minerals are finely disseminated and associated with larger amounts of pyrite and chalcopyrite than are found in the vein-matter. For this reason, the concentrates from milling operations are much higher in base-metal sulphides than are the jig concentrates or hand-sorted ore. This applies with especial force to the concentrates produced by the flotation process. The high base-metal content of these concentrates has an important bearing on their further treatment for the recovery of silver in a marketable form. Thus it has been found impossible, commercially, to cyanide flotation concentrates where these base metals predominate. These base-metal compounds are more common in the conglomerate and Keewatin wall-rock. The treatment of ores occurring in the diabase gives a clean grade of concentrate, from which the silver can be recovered without difficulty by the cyanide treatment.

The grade of the concentrates varies with the nature of the ore. Thus, where the silver values are evenly distributed throughout the vein-matter, table concentrates are produced which may carry as high as 4,000 ounces of silver to the ton. If, on the other hand, the values are irregularly distributed, the concentrates may contain as little as 500 ounces of silver to the ton, owing to the presence of large amounts of low-grade smaltite and niccolite, together with the base-metal sulphides, pyrite, arsenopyrite, etc.

The losses in the tailing will vary with the character and the grade of the ore. The principal loss is in the fines resulting from the unavoidable sliming of some of the high-grade vein-matter during crushing, and from the presence in the ore of high-grade slime from decomposed veins. The fine filmy leaf silver and various brittle silver minerals, e.g., proustite and pyrargyrite, also

slime badly on crushing. As a general average for the camp it may be said that, on treating an ore containing 25 ounces of silver to the ton, a recovery of 80 per cent. of the values can be made by gravity concentration.

Suitability for Cyanidation

Owing to the complex and refractory nature of the Cobalt ores, the earlier attempts to recover the silver by cyanide treatment were disappointing. Using the standard practice of cyaniding silver ores, as then developed, it was soon found that the solution rapidly became foul and lost its dissolving efficiency; that the consumption of cyanide at times was unduly heavy; and that, to get a satisfactory extraction of the silver, a prolonged treatment was required. The solution of these early difficulties, as a result of continued research, has greatly advanced the art of cyaniding complex silver ores and made this method of treating Cobalt ores a commercial success. Some of the more important improvements developed in the Cobalt practice include the recognition of the necessity of fine grinding; the adoption of aluminium and, later, of sodium-sulphide precipitation; the reduction of the complex silver minerals by a preliminary desulphurizing treatment; and the development of processes for the recovery, in the form of bullion, of the silver content of high-grade ore and concentrates, by cyanide treatment.

Cyanicides

Nickel is the predominating cyanicide and is especially troublesome in the extraction of silver from high-grade ore and table concentrates by cyanide treatment. In the treatment of the low-grade wall-rock, copper and iron, occurring as base-metal sulphides, together with other compounds, account for most of the cyanide consumed.

The cleanest ore from the standpoint of cyanide treatment is native silver in a calcite gangue. Table concentrates contain a certain amount of base-metal sulphides, and are more difficult to treat than high-grade ore and jig concentrates. In flotation concentrates, excepting only those produced by the treatment of ores occurring in the diabase, these base-metal compounds predominate, and on account of the heavy consumption of cyanide they cannot be treated by cyanidation.

The various processes for the treatment of high-grade ore and concentrates by cyanidation usually involve a preliminary treatment for the removal of these cyanide-consuming elements.

The effect of the different cyanicides is well illustrated by the results of the following test:—

The Ore.—A sample of niccolite and smaltite, containing a trace of silver, together with various base-metals.

Treatment.—The sample was ground with flint pebbles, in a small Abbé mill, to pass a 200-mesh screen. It was then given a cyanidation treatment in a two-liter bottle, with agitation on a wheel.

TABLE I.—DETAILS OF CYANIDE TREATMENT

Weight of ore.....	50 grammes.
Time of treatment.....	24 hours.
Dilution of pulp at finish.....	24:1 (by weight).
Lime added per ton of ore.....	10 lbs.
Strength of cyanide maintained at 0.5 per cent. KCN.	
After treatment the cyanide consumed, per ton of ore..	1077.3 lbs. NaCN.

ANALYSIS OF SOLUTION AFTER CYANIDE TREATMENT

Element	Per cent. in solution	Amount of metal in lbs. per ton of ore	NaCN tied up, lbs. per ton of ore
Fe.....	0.046	32.08	116.18
Cu.....	Nil	Nil	Nil
Zn.....	0.090	43.20	129.56
Ni.....	0.470	225.60	754.72
Co.....	0.020	9.60	47.90
NaCNS.....	0.038	18.24	18.24
As.....	0.408	195.84	.. ..
			1066.60

Comments

1. Assuming that the metals are present as double cyanides, the percentages of these elements in the solution would account for a total cyanide consumption of 1066.6 pounds. The test showed a real consumption of 1077.3 pounds NaCN, the difference of 10.7 pounds being unaccounted for.

2. The above sample is not representative of the high-grade ore being treated by the cyanide process, since it contains a considerable amount of zinc and only a trace of silver. The test, however, does indicate very clearly the fact that the nickel compounds are the predominating cyanicides.

Cyaniding Low-Grade Ore

Owing to the good results obtained by straight concentration, and the difficulties experienced in the earlier attempts at cyaniding, the dumps and low-grade ore were at first treated exclusively by concentration, and the concentrates sold to the smelters. Later, certain of these mills added a cyanide annex to treat the slime tailings, the lower-grade sands going to waste. Later still at the O'Brien mill, after a preliminary concentration on tables, which recovered 40 per cent. of the silver as a high-grade concentrate, the ore was crushed to 80 per cent. through a 200-mesh screen, and the remaining values extracted by cyanide treatment, using aluminium-dust precipitation. The Nipissing low-grade plant was the first mill to treat the ore by an all-cyanide process below the stamps. From time to time, various changes were made in all of these plants to bring the treatment into line with the newer developments in practice, and to adapt the process to changing conditions in the nature and grade of the ore, changes in marketing conditions, and changes in the cost of materials, as a result of the dislocation of industry by the Great War.

The fouling of the working-solution, with the consequent loss of dissolving efficiency, was found to be due to the introduction of zinc into a solution carrying considerable amounts of dissolved arsenic and antimony. This was corrected by substituting aluminium for zinc as the precipitant, since aluminium forms no compounds with cyanide. The use of aluminium also effected an important saving in cyanide consumption.

Clean native silver in a calcite gangue dissolves readily in cyanide solution, giving a high extraction, as do also the filmy brittle leaf and the high-grade slime from decomposed veins. On the other hand, impure native silver, high in antimony and grading into dyscrasite, dissolves very slowly and requires a prolonged

treatment. Of the silver compounds, argentite yields to treatment without difficulty, but with proustite and pyrargyrite the extraction is low, and when these minerals are present in the ore, the tailing from the cyanide treatment is relatively high.

Owing to the refractory nature of these minerals, extremely fine grinding is essential to dissolution, in order to obtain a satisfactory extraction within a reasonable time of treatment. Failure to recognize this fact was responsible for much of the 'grief' and unsatisfactory results of the earlier operators. In the present practice of the Nipissing low-grade mill, the 200-mesh sands are ground to a true slime by means of iron balls in tube-mills, operating in closed circuit with Dorr bowl classifiers.

The extraction of the silver from the complex silver minerals is, for the most part, greatly improved by giving the ore a preliminary desulphurizing treatment with aluminium in a solution of caustic soda, before sending it to the cyanide tanks. By this treatment these minerals are reduced to their elements, leaving the silver as a spongy metal, in which condition it is readily soluble in cyanide solutions. As these silver minerals are not characteristic of the ore as a whole, but rather are found localized in certain veins and sections of veins, this preliminary desulphurizing treatment is not applicable to the general ore of the camp.

Cyanide in Treatment of High-Grade Ore and Concentrates

The advantages of shipping only fine bullion led to the development of various processes for the local treatment of high-grade material, but more especially hand-sorted ore and jig and table concentrates. The processes involving the use of cyanide for the extraction of the silver include the following:

(a) *The Amalgamation and Cyanidation Process.*—This was used at the Nipissing high-grade mill and later at the Buffalo mill. Pan amalgamation was also used at the Dominion Reduction plant. In this treatment cyanide played a very subordinate part. In the Nipissing practice an extraction of 97 per cent. of the silver was obtained by amalgamation in the tube-mill, leaving an extraction of only 3 per cent. for the cyanide process.

(b) *The Hypochlorite-Cyanidation Process.*—This process was developed by the joint efforts of the Cobalt Reduction and Nipissing Mines, and is still in use at the Cobalt Reduction plant. At the Nipissing it replaced the older amalgamation process, owing, among other reasons, to the increased cost of mercury. The process involves the oxidation of the base-metal compounds by a preliminary treatment of the ore with hypochlorite, before sending it to the cyanide tanks. An extraction of 97 per cent. of the silver in the ore in the form of fine bullion is effected in a treatment period of ninety-six hours.

(c) *The Sulphuric Acid-Cyanidation Process.*—This was introduced at the Nipissing high-grade mill where it has replaced the former hypochlorite treatment. It involves the removal, before cyanidation, of the decomposed nickel compounds by a preliminary treatment with dilute sulphuric acid. The results are similar to those from the hypochlorite treatment, but on decomposed material a greater saving in cyanide is effected.

(d) *Chloridizing Roast.*—This process was used at the Buffalo mill for the treatment of flotation concentrates. It consisted of a preliminary chloridizing roast in the Holt-Dern furnace, followed by a weak acid-wash to eliminate the cyanicides, especially copper, after which the pulp was treated by cyanidation.

Suitability for Flotation

In the enthusiasm that followed the introduction of the flotation process, high hopes were entertained as to the possibilities of this method of concentrating Cobalt silver ores. Indeed, the many advantages claimed for the new process, such as its high efficiency, low treatment costs, and inexpensive installation, led some of its exponents to hope that it would displace entirely the older methods of treatment by gravity concentration or cyanidation, and completely revolutionize the established practice of ore treatment. But these hopes have largely failed of realization. The flotation process is not so efficient in the treatment of Cobalt ores as was at first anticipated. As against the cyanide process, flotation produces only a concentrate instead of fine bullion. As against gravity concentration, the flotation concentrate is expensive to market: it is relatively low in silver and high in silica; it is high in base-metal sulphides and low in cobalt arsenides, and the latter are now valuable by-products. For these reasons flotation concentrates are not desired by the Canadian smelters. At the present time they are marketed in the United States.

The various minerals in the ore respond differently to the flotation treatment. Thus fine leaf silver floats readily, as do also argentite, and the ruby silvers, proustite and pyrrargyrite. Antimonial silver and dyscrasite, and the silver in the high-grade slimes from oxidized veins, are recovered less readily. The base-metal sulphides are raised easily, but the arsenides are floated with difficulty.

The result of the flotation treatment on some of the more important silver minerals in the Cobalt ores is shown in the following table:—

TABLE II.—RESULT OF FLOTATION TREATMENT ON SILVER MINERALS

Mineral	Head assay	Tail assay	Concentrate assay	Extraction
	oz. Ag.	oz. Ag.	oz. Ag.	per cent.
Silver (native silver minus 100 plus 200 mesh) . .	15.56	12.20	482.00	22.23
Silver (native silver minus 200 mesh)	20.48	6.00	1377.00	71.04
Silver (refined silver minus 100 plus 200 mesh) .	12.53	3.30	512.00	74.14
Silver (refined silver minus 200 mesh)	15.67	2.70	632.00	83.15
Argentite	30.41	8.85	1972.43	71.22
Proustite	19.75	7.62	1824.97	61.82
Pyrrargyrite	33.33	8.64	1524.52	74.49
Matildite	22.05	14.03	973.57	36.91
Freieslebenite	9.63	4.96	421.55	49.15
Freiburgite	19.99	4.52	534.25	78.03

Comments

1. Samples for the above tests were prepared by adding picked specimens of these minerals to a sand-tailing containing approximately 3.5 ounces of silver to the ton. The sample was then ground dry, to pass a 100-mesh screen, with flint pebbles in an Abbé mill.

2. Testing was done by treating samples of 1000 grammes for thirty minutes in a mechanical frothing machine, at a dilution of 4:1. An oil mixture, containing 70 per cent. creosote, 10 per cent. coal tar, and 20 per cent. pine oil, was added to the amount of one and a half pounds per ton of ore.

3. The effort was made to produce a high-grade concentrate and a tailing in one operation.



Fig. 60—Temiskaming mill and shaft-house.



Fig. 61—McKinley-Darragh-Savage mill.

CRUSHERS AND CRUSHING

Introduction

Every mining camp presents many problems that are peculiar to itself, the solution of which will depend on the particular conditions prevailing in the district. This applies as much to the crushing of the ore from any camp as to the mining or metallurgical treatment of it. Each is a problem to be solved on its own merits. For this reason, it is unsafe to indulge in broad generalizations and to attempt to impose the solution of such a problem for one region, under a given set of conditions, on another region where the conditions are entirely different.

The crushing practice of the Cobalt area, arrived at by a process of trial and elimination, represents the best solution of that problem for this district, under the conditions imposed. Some of these governing conditions are the low tonnages treated, the hardness and toughness of the rock, the richness of the ore, and the desirability of sliming or non-sliming.

Coarse Crushing

For these reasons, the Blake or jaw crusher is favoured as the primary breaker, owing to the ability of a medium-size machine of this type to take the run-of-mine ore, and break it to 2-inch to 4-inch cubes. A breaker of the gyratory type, capable of handling the larger pieces of rock, would be out of all proportion to the capacity of the rest of the mill. A medium-size gyratory is generally used as a secondary crusher, discharging a product of 1 inch to 2 inches.

Intermediate Crushing

With Cobalt ores stage-crushing followed by concentration is not practicable. After the preliminary hand-sorting and jigging treatment, approximately 70 per cent. of the values are liberated on reducing the ore to 16-20 mesh. This will permit the elimination of a sand tailing carrying three to four ounces of silver to the ton. For gravity concentration, sliming of the valuable minerals should be reduced to a minimum. The work of the intermediate crusher, therefore, is to reduce a feed of 1 inch to 2 inches to 16-20 mesh, in one operation, with a minimum production of fines. For this purpose at some time or other, practically all the standard machines have been tried out in the camp. These include gravity stamps, rolls, the Huntingdon mill, the Chilian mill, the Symons disc, the Hardinge mill, and various types of ball-mills: the Krupp, Gates, Chalmers, and Marcy, as well as combination ball-and-pebble mills. These machines were used with varying degrees of success. A comparison of their performance is impossible for various reasons, one of which is that the conditions under which they were used were not always parallel. In the ball-mills and tube-mills, all the standard liners have been tried. The present practice is to use liners of manganese steel in the ball-mills for coarse crushing, and chilled iron in the tube-mills for fine grinding.

Gravity Stamp Best for Intermediate Crushing

As an intermediate crusher, however, the gravity stamp has proved its superiority over all other types and combinations of machines. The smashing blow of the stamp is particularly effective in reducing the tough Cobalt rock to

a granular product with a minimum of slime, which is very suitable for table concentration. It is therefore no accident that the use of this machine has always predominated in the camp and that at the present time all the ore being treated is crushed in stamp batteries.

The stamp has won its present position of popularity in the Cobalt camp on its merits as an intermediate crusher. Some of its advantages may be summarized as follows:—

1. Its efficiency and low operating cost.
2. Its simplicity and reliability.
3. The stamp as a unit is the same for a small mill as for a large mill. For this reason the small installation is just as efficient as the larger one.
4. Its wide crushing range. The stamp will take a 2-inch feed and reduce it efficiently, in one operation, to any size down to 16 mesh. The stamp duty, of course, is lower with the finer discharge.
5. Its ability to discharge a product that is very suitable for concentration on tables.

The present practice is to use coarser screens on the stamps and after a roughing treatment on tables, to re-grind in tube-mills or Hardinge mills loaded with iron balls. Details of practice are given later in the descriptions of various milling plants.

Tube-Mills for Fine Grinding

For fine grinding, the tube-mill is used in nearly every instance, though a few plants use the Hardinge mill for this purpose. In tube-milling the important factors are: the load circulating through the mill, the dilution of the pulp, the size of the balls, and the size and character of the feed. On these points details are given later in the descriptions of actual practice.

The present tendency is to substitute iron balls for flint pebbles in the tube-mills. These are used in sizes ranging from 1 inch to 4 inches, depending on the size of the feed to the mill. A mill loaded with iron balls shows a marked increase in tonnage over one using flint pebbles, provided each is loaded to the centre, volume for volume. The cost of grinding is about the same in each case, as the consumption of power increases in proportion to the tonnage ground. The saving effected is that the output is enlarged without increasing the number of machines. Crushing with iron balls has the additional advantage of enabling the tube-mill to take a coarser feed. At the Coniagas mill, material as coarse as $\frac{1}{2}$ inch is now being ground in tube-mills using 4-inch iron balls. At this plant the substitution of iron balls for pebbles has made possible a large increase in daily capacity without installing additional equipment.

Economic Limit of Crushing

The economic limit of crushing depends on the subsequent treatment of the ore. It is that point where the least crushing will liberate the most values, in a readily recoverable form. For gravity concentration this limit is about 16 mesh, as at this point the easily liberated values are set free, permitting the discharge of a sand-tailing averaging three to four ounces of silver to the ton. The sliming of the ore must be avoided as far as possible, as when once slimed, a certain amount of the values will float away, and no amount of mechanical concentration will save them. It is now recognized that, in the early days of the camp, the general tendency was to over-grind the ore preparatory for gravity concentration, causing an undue loss of values in the slimes. In the milling of the higher grades of ore, this is a point of vital importance.

The following tables give screen analyses of the stamp discharge at the Coniagas, O'Brien, and Nipissing mills, the Coniagas using coarse screens and the O'Brien a finer (14-mesh) screen. These tables illustrate clearly the nature of the crushing done and show the distribution of the values in the various products.

TABLE III.—SCREEN ANALYSIS OF STAMP DISCHARGE

Coniagas mill, February 27th, 1923: Opening in battery screen, $\frac{3}{8}$ by $\frac{5}{8}$ in. or 9.525 m.m. by 15.875 m.m.; assay of general sample, 10.0 oz. of silver per ton; dilution, 5.5:1; tons per stamp in 24 hours, 5.53.

Mesh	Per cent.	Assay value	Per cent. Ag. value
On 6	28.29	4.4	12.81
" 6-8	10.31	6.2	6.61
" 8-10	10.22	11.0	11.57
" 10-14	7.95	9.2	7.53
" 14-20	8.04	8.0	6.61
" 20-28	7.10	14.5	10.64
" 28-35	7.00	11.2	8.06
" 35-48	3.12	12.8	4.13
" 48-65	2.55	21.4	5.69
" 65-100	2.84	18.1	5.27
" 100-150	1.32	19.0	2.59
" 150-200	1.70	26.2	4.65
Minus 200	9.56	14.0	13.84

TABLE IV.—SCREEN ANALYSIS OF STAMP DISCHARGE

Coniagas mill, April 15th, 1923: Opening in battery screen, $\frac{3}{4}$ by $\frac{1}{2}$ inch or 19.050 m.m. by 12.700 m.m.; assay of general head, 10.0 oz. of silver per ton; tons per stamp in 24 hours, 6.36.

Mesh	Per cent.	Assay value	Per cent. Ag. value
On 6	35.95	4.2	14.40
" 8	9.92	7.3	6.90
" 10	8.25	8.5	6.66
" 14	8.52	12.5	10.20
" 20	4.42	18.1	7.60
" 28	6.57	12.2	7.60
" 35	3.93	22.2	8.30
" 48	3.88	20.1	7.40
" 65	3.11	20.1	6.00
" 100	2.51	20.6	5.00
" 150	2.18	16.2	3.80
" 200	1.14	28.8	2.84
Minus 200	9.56	14.8	13.30

TABLE V.—SCREEN ANALYSIS OF STAMP DISCHARGE

O'Brien mill, April 30, 1923: Opening of battery screen, 0.0212 by 0.2811 in., or 0.5386 m.m. by 7.276 m.m. (14 mesh); assay of general head, 14.6 oz. of silver per ton; tons per stamp in 24 hours, 2.78.

Mesh	Per cent.	Assay value	Per cent. Ag. value
On 14	3.00	4.4	0.9
" 20	9.34	5.0	3.3
" 28	11.10	11.2	8.8
" 35	10.18	18.1	13.1
" 48	9.34	17.3	11.6
" 65	7.96	14.6	8.3
" 100	8.96	14.8	9.5
" 150	6.89	15.8	7.8
" 200	5.75	19.0	7.8
Minus 200	27.49	14.7	28.9

TABLE VI.—SIZING ANALYSIS ON BATTERY DISCHARGE

Nipissing Mines: 40–1500 stamps; 8-inch drop, 100 drops per minute, using 4-mesh screens on batteries (16 holes to sq. in.) Dilution of pulp, 3.3:1.

Screen size	Battery discharge	Cumulative
	per cent.	per cent.
+ 4	0.0	.....
- 4+ 6	3.822	.....
- 6+ 8	5.755	9.577
- 8+ 10	6.307	15.884
- 10+ 14	4.696	20.580
- 14+ 20	4.696	25.276
- 20+ 28	4.604	29.880
- 28+ 35	4.374	34.254
- 35+ 48	4.696	38.950
- 48+ 65	3.729	42.679
- 65+100	5.202	47.881
- 100+150	3.039	50.920
- 150+200	6.492	57.412
- 200	13.444	70.856
Slime	29.144	100.000

For flotation, the economic limit of crushing is about an 80-mesh sand, though this will vary considerably with the character of the ore. Excessive sliming should be avoided, as the fine slimes give a poor recovery by this treatment.

The work done by flotation is shown in the screen analyses of the heads and tailings at the Coniagas and O'Brien mills, as given in the following tables. These analyses show the distribution of the values in the different sizes, and how the various sizes respond to the flotation treatment.

TABLE VII.—SCREEN ANALYSIS OF FLOTATION HEAD

Coniagas mill, February 27, 1923: Assay of general sample, 3.5 oz. of silver per ton.

Mesh	Per cent.	Assay value	Per cent. Ag. value
On 48	1.05	8.5	2.56
" 48-65	3.35	1.7	1.70
" 65-100	10.27	1.8	5.11
" 100-150	8.70	2.1	5.11
" 150-200	15.20	2.8	12.22
Minus 200	61.43	4.2	73.30

TABLE VII (Continued).—SCREEN ANALYSIS OF FLOTATION TAILINGS

General sample, 1.5. oz. of silver per ton.

Mesh	Per cent.	Assay value	Per cent. Ag. value
On 48	1.48	2.2	2.01
" 48-65	4.36	1.7	4.70
" 65-100	11.54	1.4	10.74
" 100-150	9.66	1.1	7.38
" 150-200	15.37	0.9	9.40
Minus 200	57.59	1.7	65.77

TABLE VIII.—SCREEN ANALYSIS OF FLOTATION HEAD

Coniagas mill, April 15, 1923: Assay of general head, 3.3 oz. of silver per ton.

Mesh	Per cent.	Assay value	Per cent. Ag. value
Plus 48	0.66	5.3	1.1
" 65	1.98	5.3	3.1
" 100	7.42	2.2	5.0
" 150	14.30	1.7	7.4
" 200	8.08	2.1	5.2
Minus 200	67.56	3.8	78.0

TABLE VIII (Continued).—SCREEN ANALYSIS OF FLOTATION TAIL

General tail, 1.3 oz. of silver per ton.

Mesh	Per cent.	Assay value	Per cent. Ag. value
Plus 48	1.33	1.7	1.5
" 65	3.74	1.7	4.6
" 100	11.12	1.2	10.0
" 150	13.35	0.8	8.4
" 200	10.14	0.8	6.1
Minus 200	60.32	1.5	69.2

TABLE IX.—SCREEN ANALYSIS OF FLOTATION HEAD

O'Brien mill, April 30th, 1923; general head 4.8 oz. of silver per ton.

Mesh	Per cent.	Assay value	Per cent. Ag. value
Plus 65	2.20	3.0	1.4
" 100	10.86	2.8	6.2
" 150	13.72	2.3	6.7
" 200	9.83	2.6	5.4
Minus 200	63.39	6.1	80.3

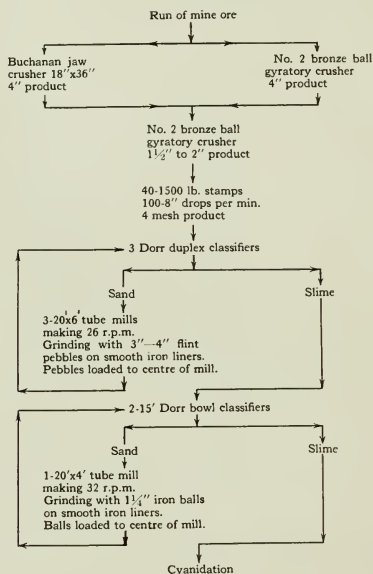
TABLE IX (Continued).—SCREEN ANALYSIS OF FLOTATION TAIL

General tail, 2.0 oz. of silver per ton.

Mesh	Per cent.	Assay value	Per cent. Ag. value
Plus 100	7.45	2.0	8.0
" 150	12.23	1.5	9.0
" 200	12.62	1.5	10.0
Minus 200	67.70	2.1	73.0

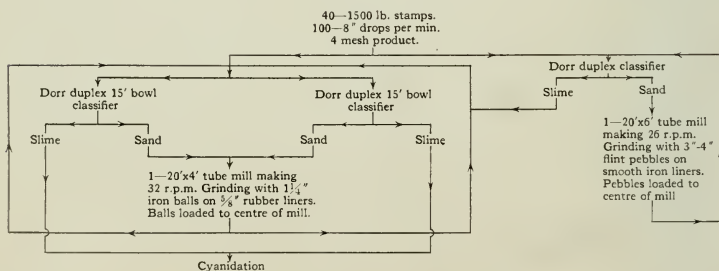
For cyanidation, owing to the refractory nature of the ore, excessively fine grinding is required to obtain dissolution of the values in a reasonable time of treatment. This is carried to the ultimate degree at the Nipissing low-grade mill, where the 200-mesh sands are ground to an impalpable slime with 1¼-inch iron balls, in tube-mills working in closed circuit with Dorr bowl classifiers.

TABLE X



Nipissing Mining Company, Ltd.—Flow-sheet (1922) of preliminary crushing and fine grinding of the run-of-mine ore to -200 mesh product. The present practice (1923) with one tube-mill lined with rubber, is shown in table Xa.

TABLE Xa



The Cost of Crushing

Tables XI and XII give detailed costs of crushing at the Nipissing low-grade mill and the Cobalt Reduction Company's mill.

TABLE XI.—COST OF REDUCING RUN-OF-MINE ORE TO MINUS 200 MESH BY STAGES, NIPissing MILL, YEARS 1913-1922, INCLUSIVE

Stages	Labour			Replacements and supplies		Power		Shops		Totals	
	Tons	Total cost	Cost per ton	Total cost	Cost per ton	Total cost	Cost per ton	Total cost	Cost per ton	Cost	Cost per ton
CRUSHING 1 18 by 36-inch jaw crusher at mine, and 2 No. 4 gyratory crushers, product reduced from run of mine to 1½ inches . .	3774,926	\$91,811.41	\$0.119	\$40,314.61	\$0.052	\$20,523.10	\$0.026	\$13,851.66	\$0.018	\$166,500.78	\$0.215
STAMPING 40 1500-lb. stamps, product reduced from 1½ inches to 4-mesh	774,926	77,038.24	0.099	56,912.80	0.073	82,658.69	0.107	25,160.82	0.033	241,770.55	0.312
TUBE-MILLING Including classification; 3 20 by 6-ft. tube-mills grinding with flint pebbles. 1 20 by 4-ft. tube-mill re-grinding product from pebble-mills with 1¼-inch iron balls, product reduced from 4-mesh to minus 200-mesh fine slime	774,926	101,876.16	0.132	171,551.00	0.222	251,851.12	0.325	38,415.68	0.048	563,693.96	0.727
Totals . . . . .	.....	\$270,725.81	\$0.350	\$268,778.41	\$0.347	\$355,032.91	\$0.458	\$77,428.16	\$0.099	\$971,965.29	\$1.254

Table XII gives the cost of crushing ore at the Cobalt Reduction works for a full year, namely, from June 1st, 1921, to May 31st, 1922:—

TABLE XII.—CRUSHING COSTS AT COBALT REDUCTION COMPANY MILL

Layout consisting of one No. 5 McCully crusher.
two No. 4 "K" Gates crushers.
one 6 ft. by 3 ft. by 1½-inch sizing trommel.
one 20 by 6-inch Blake type jaw crusher.
Ore reduction from 9 inches mine run to 1½ inches to stamps.

Tons crushed.....	97,050	
Hours run.....	3,600	
Tons per hour.....	26.958	cents
Operating cost per ton (labour).....		3.692
Repair " " " (labour).....		2.488
Repair " " " (material).....		3.342
Power " " ".....		3.091
		12.613

COST OF STAMPING

Layout consisting of:—
75-1260 lb. stamps, 7½ inches drop, 104 drops per minute.
Screens—3-mesh double crimped steel wire gauge .078125 inch.
Running time, approximately 96 per cent.
Chrome steel shoes; hard iron dies.

Tons stamped.....	97,050	cents
Operating cost per ton (labour).....		6.998
Repair " " " (labour).....		3.588
Repair " " " (material).....		12.089
Power " " ".....		10.904
		33.579

COST OF TUBE-MILLING, GRINDING TO 40 MESH

Product: plus 200-mesh, 45 per cent.; minus 200-mesh, 55 per cent.

Layout consisting of:—

One 5 by 20 tube-mill, 26 r.p.m. 60 H.P. Motor, 70.54 H.P.
Ball load, 18,000 lbs.
One 4 by 20 tube-mill, 29 r.p.m. 50 H.P. Motor, 70.90 H.P.
Ball load, 16,000 lbs.
One 5 by 16 tube-mill, 25 r.p.m. 50 H.P. Motor, 80.93 H.P.
Ball load, 16,000 lbs.
Liners, hard iron.
Balls, 2-inch hard iron.

Tons ground.....	97,050	cents
Operating cost per ton (labour).....		2.332
Repair " " " (labour).....		1.195
Repair " " " (balls).....		14.365
Repair " " " (liners).....		9.219
Power " " ".....		12.171
		39.282

TABLE XIII.—THE CONIAGAS MINES, LIMITED, CONSUMPTION OF SHOES AND DIES PER TON OF ORE CRUSHED—YEARS 1914-1922, INCLUSIVE

Shoe.....230 lb. to 250 lb.
Die.....130 lb. to 143 lb.

Year	Tons stamped	Shoes		Lbs. per ton	Dies		Lbs. per ton	Total lbs. per ton	Battery screens	Manufacture, material, etc.
		No.	Weight		No.	Weight				
1914.....	54,522	85	20,825	0.3819	95	13,395	0.2456	0.6275	16, 14, and 12 mesh	Shoe—Chrome steel Die — “
1915.....	55,437	105	25,620	.4622	75	10,425	.1880	.7502	16, 14 mesh	Shoe— “ Die — “
1916.....	56,973	105	25,305	.4414	85	11,815	.2073	.6514	“	Shoe— “ Die — “
1917.....	60,928	120	29,400	.4825	100	13,000	.2134	.6959	“	Shoe— “ Die —Hard iron
1918.....	68,597	95	23,750	.3463	85	11,050	.1611	.5074	8, 6 mesh	Shoe—Chrome steel Die —Hard iron
1919.....	71,743	105	24,775	.3453	95	12,350	.1721	.5174	4m.m. by $\frac{3}{4}$ -in.	Shoe—Forged steel Die —Hard iron
1920.....	97,634	160	36,800	.3699	135	19,305	.1941	.5640	3m.m. by $\frac{3}{8}$ -in.	Shoe—Chrome steel Die —Hard iron
1921.....	113,279	135	33,750	.2866	120	17,160	.1457	.4323	2m.m. by $\frac{5}{8}$ -in. and 2m.m. by 1-in.	Shoe—Chrome steel Die —Hard iron
1922.....	121,953	125	31,250	.2562	120	17,160	.1407	.3969	2m.m. by $\frac{1}{2}$ -in. and 2m.m. by 1-in.	Shoe—Chrome steel Die —Hard iron
Total.....	701,066	1,035	251,475	.....	910	125,660	.....	.....		
Average.....	.....	...	.....	0.3587	...	.....	0.1792	0.5379		

TABLE XIV.—CONSUMPTION OF SHOES AND DIES PER TON OF ORE CRUSHED, NIPISSING MINING COMPANY, LIMITED, YEARS 1915-1922, INCLUSIVE.

Shoe.... 263 lbs.
Die..... 165 lbs.

Year	Tons stamped	Chrome shoes		Chrome dies				Replacement of stems and cam shafts		
		No.	Total weight	Lbs. per ton	No.	Total weight	Lbs. per ton	Swed. iron stems	Fag. iron C.S.	Stamp duty, tons per day per stamp
1915.....	77,183	130	34,190	0.4429	130	21,450	0.2779	0	1	6.57
1916.....	76,851	100	26,300	.3422	100	16,500	.2147	3	0	6.70
1917.....	74,498	118	31,034	.4166	109	17,985	.2414	1	0	6.31
1918.....	80,274	95	24,985	.3112	83	13,695	.1706	1	3	6.98
1919.....	65,391	86	22,618	.3459	66	10,890	.1665	1	4	6.27
1920.....	81,700	101	26,563	.3251	91	15,015	.1838	0	0	6.36
1921.....	80,720	96	25,248	.3128	77	12,705	.1574	0	0	6.27
1922.....	82,025	85	22,355	.2725	56	9,240	.1126	0	0	7.05
Average.....	618,642	811	213,293	0.3448	712	117,480	0.1899	6	8	6.49

Stamp Battery Practice at Nipissing

Feeders are of the suspended Nelson type. Stamping is done in 0.12 per cent. cyanide solution, to pass a 4-mesh screen. There are forty stamps, each averaging 1,500 pounds, the weight of the various parts, when new, being as follows:—

Swedish iron stem 4 in. dia. by 16 ft. long.....	lbs. 681
Cast steel tappet, 10-1-8 by 14 in. with gib and keys ...	190
Cast steel head, 9½ in dia. by 24 in. long.....	412
Forged chrome steel shoe, 9¼ in. by 12 in.....	254
	1,537

The stamps are arranged five to a battery. The order of drop is 1, 3, 5, 2, 4. Number of drops per minute is 100. Height of drop is eight inches. Height of discharge is one and a half inches. The cam shaft is of the Blanton fluted type, seven inches in diameter. The mortars are Fraser and Chalmers No. 161 type, for rapid discharge, and weigh, with steel liners, 12,410 pounds each. A rubber pad ¼-inch thick is placed between the mortar and the concrete mortar-block. A 40-horsepower motor is used to drive each battery of ten stamps. The stamp duty is from 6.01 to 7.05 tons every twenty-four hours.

The average daily stamp-duty at the Nipissing mill, over a period of ten years, is shown in the following table:—

TABLE XV.—STAMP DUTY, NIPISSING MILL

	Screen mesh per inch
1913—6.09 tons per stamp per day.....	8 by 8 and 4 by 4
1914—6.01 " " " "	8 by 8 and 4 by 4
1915—6.57 " " " "	3 by 3 and 2 by 2
1916—6.70 " " " "	3 by 3 and 2 by 2
1917—6.20 " " " "	3 by 3 and 2 by 2
1918—6.98 " " " "	4 by 4
1919—6.27 " " " "	4 by 4
1920—6.36 " " " "	4 by 4
1921—6.26 " " " "	4 by 4
1922—7.05 " " " "	4 by 4

Rubber Liner for Tube-Mill

An experiment of more than ordinary interest is now in progress at the Nipissing mill. In the endeavour to reduce the cost and improve the grinding in tube-mills, the idea suggested itself, owing to its resiliency and wearing qualities, of using rubber as a liner, instead of hard iron or manganese steel.

Experimental grinding tests with rubber as a liner were carried out in 1921, in a 3-ft. by 18-inch tube-mill. After several months the results of these tests were so encouraging that it was decided to try the experiment on a commercial scale. A slab of rubber 3 ft. wide, 12 ft. 9 inches long, by $\frac{5}{8}$ inches thick, was fitted in a 4-ft. by 20-ft. tube-mill, grinding a 4-mesh and finer product, and loaded with $\frac{1}{4}$ -inch iron balls. After three months of continuous operation the rubber was removed and weighed. The loss in weight was so small as to warrant the complete lining of a tube-mill.

In January, 1923, a 4-ft. by 20-ft. tube-mill was put into operation, loaded with $\frac{1}{4}$ -inch iron balls and lined with rubber throughout. To date (July 1st, 1923) the lining appears to be in good condition, and the tube-mill duty has been increased to a marked degree.

The experiment has proved conclusively that, as a grinding medium, the liner plays only a minor part. The chief function of the liner is to protect the shell of the mill.

The use of rubber as a lining may prove to be an important development in tube-mill practice. It is too early to predict just what it will mean to the industry.

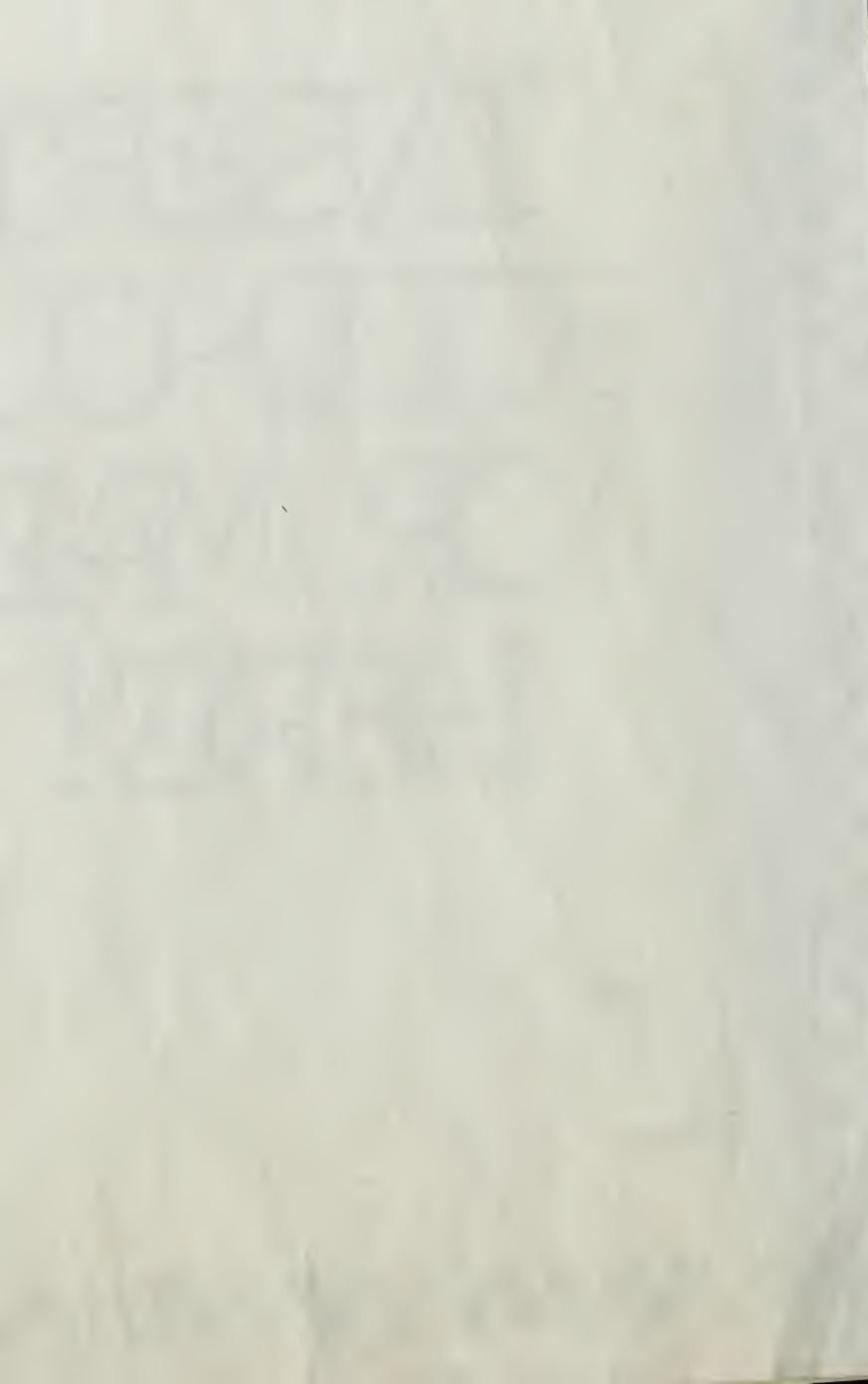
TREATMENT OF LOW-GRADE ORE

Introduction

Silver was first discovered at Cobalt in the fall of 1903, and as a result of the richness of the ore and the ease with which it was won, production started at once. Thus in 1904, a total of 158 tons of high-grade ore, containing 206,875 ounces of silver, was consigned to the smelters. For the first three years following discovery, only high-grade ore was sought, no attempt being made to extract the values from the low-grade material. Much of the ore was sacked underground, and the remainder hand-sorted in simple washing-plants.

In the summer of 1907, the McKinley-Darragh Mining Company erected and put into operation the first milling plant to treat the low-grade ore. This plant comprised a five-stamp battery, together with classifiers, a Wilfley table, and Frue vanners, and had a daily capacity of fifteen tons. Then followed the Buffalo and others in quick succession, until at one time or other a total of eighteen mills having a combined daily capacity of 2,100 tons, were engaged in recovering the values from the low-grade ore. At the time of writing (February, 1923) only five of these plants continue in operation.

The treatment of the low-grade ores by milling processes has been an important factor in increasing the production of silver from the district and prolonging the life of the camp. The high-grade ore is found in narrow cracks and veins that are extensive neither in length nor depth, and though exceedingly rich in silver, are soon worked out. This fact, together with the general failure to recognize the importance of the relatively large amount of low-grade milling ore, caused the prediction of a very short life for the Cobalt camp, which, in the early days, was variously placed at from three to seven years. The high-grade ore proved to be more extensive than was first anticipated, but even so, the transition



from a high-grade to a low-grade camp was rapid, and methods were soon sought for treating the accumulated reserves of low-grade ore. To-day the positions are completely reversed. In most of the mines, the high-grade ore is now only incidental, and the production of the camp depends very largely on the recovery of the values from the low-grade ore, by milling processes. This point is brought out clearly by the following table of silver production, taken from the Thirtieth Annual Report of the Department of Mines, which shows that about 50 per cent. of the total production has been in the form of concentrates, bullion, and residues from milling and metallurgical treatment. It will be noted too that there is no record of concentrates until the year 1908, the concentrates produced in 1907 being shipped and credited as high-grade ore.

TABLE XVI.—PRODUCTION, SILVER MINES, 1904 TO 1920

Year	No. of producing mines	Shipments and silver contents							
		Ore			Concentrates and residues			Bullion	Total
		Tons	Oz.	Av. per ton. oz.	Tons	Oz.	Av. per ton. oz.	Oz.	Value
1904..	4	158	206,875	1,309	.....	.....	.....	206,875	\$111,887
1905..	16	2,144	2,451,356	1,143	.....	.....	.....	2,451,356	1,360,503
1906..	17	5,335	5,401,766	1,013	.....	.....	.....	5,401,766	3,667,551
1907..	28	14,788	10,023,311	677	.....	.....	.....	10,023,311	6,155,391
1908..	30	24,487	18,022,480	736	1.137	1,415,395	1,244	19,437,875	9,133,378
1909..	31	27,729	22,436,355	809	2.948	3,461,470	1,174	25,897,825	12,461,576
1910..	41	27,437	22,581,714	821	6.845	7,082,834	1,030	980,633	30,645,181
1911..	34	17,278	20,318,626	1,176	9.375	8,056,189	858	3,132,976	31,507,791
1912..	30	10,719	15,395,504	1,436	11.214	9,768,228	871	5,080,127	30,243,859
1913..	35	9,861	13,668,079	1,386	11,016	8,489,321	770	7,524,575	29,681,975
1914..	32	4,302	6,504,753	1,511	12,152	8,915,958	733	9,742,130	25,162,841
1915..	24	2,865	6,758,286	2,359	11,996	10,001,548	834	7,986,700	24,746,534
1916..	28	2,177	4,672,500	2,146	8.561	7,598,011	887	7,644,579	19,915,090
1917..	28	2,288	3,271,353	1,429	13,720	6,445,243	469	8,053,318	19,401,893
1918..	38	1,456	1,401,050	962	17,958	5,793,756	323	10,466,888	17,661,694
1919..	33	850	806,341	949	15,208	4,024,212	265	6,383,764	11,214,317
1920..	35	578	668,081	1,152	9,757	3,777,812	387	6,402,423	10,846,321
Total..	.....	154,452	154,586,430	1,001	131,187	84,839,977	643	73,398,113	314,446,504
									\$192,685,816

The recovery of the values from the low-grade mill rock has been effected by three distinct processes—gravity concentration, cyanidation, and flotation. Of these, the older treatments of gravity concentration and cyanidation have been of outstanding importance, and to them must be credited, largely, the silver values won by milling operations. The flotation process is, in comparison, a recent innovation, although it plays a useful part in the recovery of values from the slimes and low-grade sands. These processes will now be discussed in some detail.

Gravity Concentration

Preliminary Treatment

Early Practice.—Early operations were confined to the recovery of high-grade ore, which was sorted from the rock as broken in the mine. Later, sorting-plants were introduced, and the run-of-mine ore passed over bumping tables. During this period, the following products were obtained and shipped to the smelters:—

1. A high-grade ore carrying from 1,000 to 4,000 ounces of silver to the ton.
2. A lower grade ore, averaging about 400 ounces.
3. A screening or grizzly-product, averaging 125 ounces.

Later Practice.—With the introduction of gravity concentration plants in 1907, the general practice was to give the ore a preliminary washing treatment before sending it on for finer crushing, with subsequent treatment on tables. The ore was crushed in breakers, and sized on screens or in trommels; the over-size from the trommel was then hand-sorted on picking belts, while the finer sizes were concentrated on Hartz or Richards jigs. The rejects from this treatment, after being de-watered, were sent to the stamp bins.

The purpose of the preliminary washing treatment was to recover portions of the high-grade vein-matter broken into the mill-rock. The product was a clean high-grade ore, and represented about 50 per cent. of the total values recovered by the milling operations. It was desirable to recover this material without subjecting it to finer crushing, owing to the tendency of the high-grade ore to slime, with a consequent loss of some of the values.

Present Practice.—As a result of changing conditions, the tendency of later years has been to abandon the preliminary treatment, and at the present time there are no washing plants in operation. Later improvements in practice, and the lowering of the grade of the ore, are contributing causes leading to this change. With the impoverishment of the ore and the necessity of milling a constantly decreasing grade of wall-rock, the cost of recovering the small amount of high-grade vein-matter by a sorting and jigging treatment became unduly high. The elimination of the preliminary treatment was assisted, also, by various improvements in practice, of which the most outstanding was the development of the flotation process for the recovery of values from the slimes. It was found that gravity concentration, followed by a re-treatment of the slimes either by flotation or cyanidation, would effect a satisfactory recovery of the small amount of high-grade present in the ore. Similar satisfactory results were obtained in cyanidation by recovering much of the high-grade as a coarse concentrate by gravity concentration, prior to fine grinding for cyanide treatment. Thus, at the Nipissing low-grade mill, table concentration below the stamps has made unnecessary the more expensive preliminary washing-treatment above the stamps. In addition to a lower treatment cost, these changes have shown a marked improvement in practice. The elimination of the washing-plant has simplified the flow-sheet of the ore-treatment processes, a thing much to be desired. Table concentration removes the high-grade silver values more completely than did the former sorting practice, and so takes care of all fluctuations in the value of the feed to the mill. The grade of the ore, after concentration on tables, is thus more or less standardized, and this helps to stabilize the subsequent treatment by flotation or cyanidation.

Treatment Below the Stamps

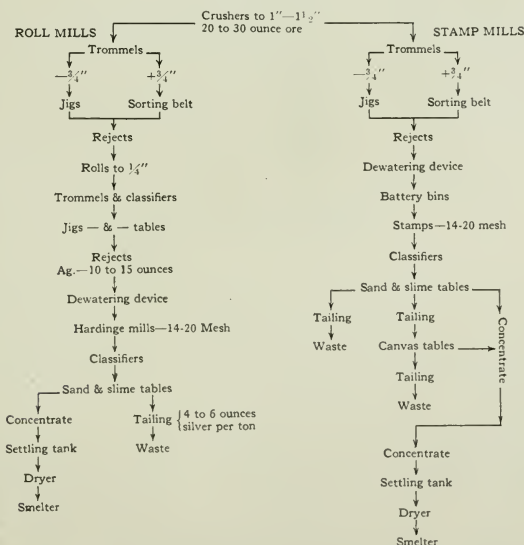
General.—Following finer crushing to liberate the values in the wall-rock and low-grade vein-matter, the treatment of the ore by gravity concentration shows a considerable variation in the methods used to recover the values. For this purpose all the standard machines and devices known—reciprocating tables, both sand and slime tables, vanners, buddles, and canvas tables—have been tried out at some time or other. Of all these, the reciprocating table has been used most widely from the beginning of operations down to the present time. The tables used include all the standard machines on the market—Wilfley, James, Deister, and Overstrom tables for the sands, and James and Deister tables for the slimes. All of these have given satisfactory results, at a low cost.

Concentration on tables is effective on sizes ranging from $\frac{1}{2}$ -inch to 200 mesh and finer. The ratio of concentration is very high, being as much as 125

to 1. The sand tables recover a high-grade concentrate, containing from 500 to 4,000 ounces of silver to the ton and discharge a low-grade tailing assaying from 2.5 to 4 ounces of silver to the ton. The slimes are concentrated less readily. Working on a feed assaying 15 ounces of silver to the ton, the slime tables make a concentrate containing 400 to 3,000 ounces of silver, and discharge a tailing assaying 7 ounces of silver to the ton. The recovery effected will depend on the character of the ore and the skill of the operator. The re-treatment of this slime tailing on canvas tables will recover another ounce of silver as a low-grade concentrate assaying from 125 to 200 ounces of silver to the ton.

Early Practice.—The early practice was to crush rather fine through 20, 30, 40 mesh, and classify closely into sand and slime. Crushing was effected in stamps, Chilean mills, Huntingdon mills, Ball mills, and Hardinge mills. The sand was treated on James, Wilfley, Deister, and Overstrom tables, making a low-grade sand tailing which went to waste, and a clean high-grade concentrate which was dried and shipped to the smelter. The middling, either with or without re-grinding, was retreated on middling tables, making a concentrate and a tailing which was discharged with the general sand tailing. The overflow from the classifier, after thickening in Callow cones or Dorr thickeners, was treated on slime tables or vanners, and the tailings, after re-treatment on canvas tables, were either impounded or sent to waste. The concentrates from the slime tables and canvas tables were dried and shipped. With certain modifications, this continued to be the general practice in gravity concentration until the introduction of the flotation process in 1916. This is shown in skeleton outline in the following flow-sheet:—

TABLE XVII

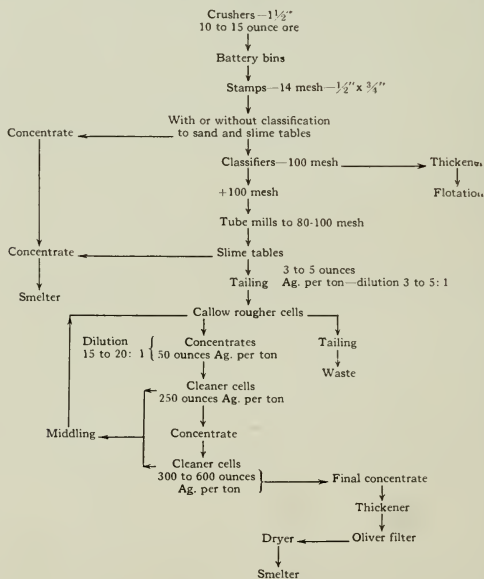


Flow-sheet of early practice in gravity concentration to 1916.

Present Practice.—The present practice in gravity concentration dates from the introduction of the flotation process in 1916, when the improvement in the treatment of slimes, together with the higher price of silver and the falling off in the general grade of the ore, made certain changes in operation necessary and desirable. The preliminary sorting and jigging treatment was discontinued, and the stamp duty increased by the use of coarser battery-screens. The older practice was still followed, of recovering as much of the values as economically possible by gravity concentration on sand and slime tables, the tailing from the slime tables going direct to the flotation plant. The sand tailing, which formerly was sent to waste, was now re-ground and sent to the flotation machines. The re-grinding of the sands was done in tube-mills, using a silex lining and flint pebbles. Later developments resulted in substituting iron balls for the pebbles.

The resulting practice now in general use is shown in skeleton outline in the following flow-sheet:—

TABLE XVIII

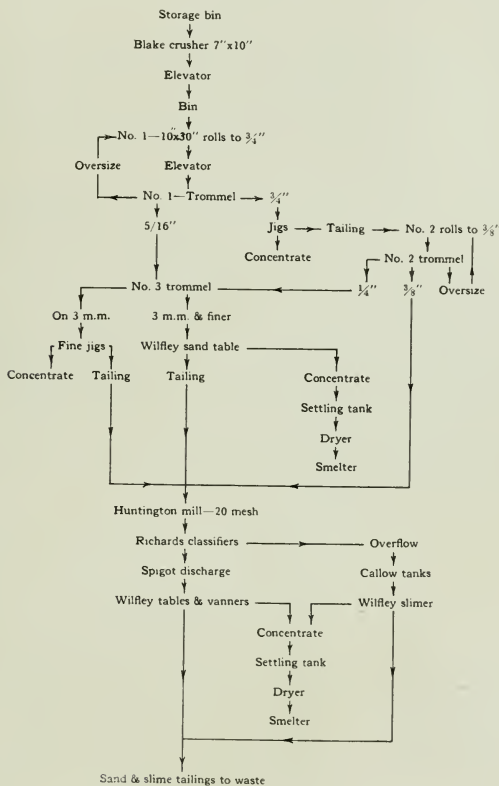


Flow-sheet showing general practice in gravity concentration and flotation.

Outline of Coniagas Practice

The various changes made in concentration, as applied to the ores of Cobalt, and the development of the art to meet changing conditions, are well illustrated in the following outline of the practice of the Coniagas concentrator. This plant was started on September 24th, 1907, and was the second mill to begin operating in Cobalt. It had a daily capacity of sixty tons. The original flow-sheet was as follows:—

TABLE XIX



Coniagas mill, original flow-sheet.

Early Practice.—Much trouble was experienced in the crushing section of this plant, and it was soon discovered that the equipment was too light for the work. The rock was found to be very hard and tough, causing a heavy breakage of crusher parts, and excessive wear and tear on the rolls and Huntington mill. A Krupp ball mill was tried out, but the results were not satisfactory. A test was then made with stamps, using the 5-stamp mill of the McKinley-Darragh. As a result of these tests the Coniagas plant was remodelled and thirty stamps were installed in 1908. These were later increased by an additional thirty stamps. With sixty stamps crushing to 16-mesh, the mill had a daily capacity of 180 tons.

For some time a system of straight gravity concentration was used. The ore, after crushing, was given a preliminary sorting and jigging treatment, the rejects being sent to the battery bins. The battery discharge was concentrated

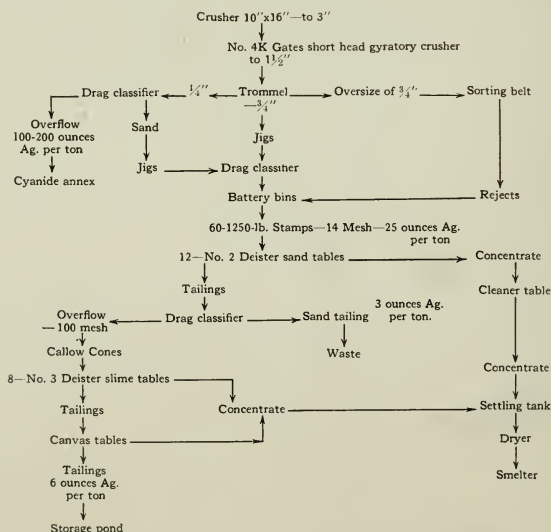
on Deister sand and slime tables, and the tailing from the slime tables was re-treated on canvas tables. The sands were sent to waste, and the slime tailing was impounded.

A point of some interest was the use in this plant of a pilot-table to check the work of the concentrating tables. A continuous sample, cut from the tailing going to waste, was fed over a regular No. 2 Deister table, and the feed and the tailing from this table were assayed daily. The use of this pilot-table had also a good moral effect on the operators, since the amount of free mineral on the same afforded a continuous record of the efficiency of the work being done by the other tables in the mill.

Later Practice.—Later, when a number of oxidized veins were developed, trouble was experienced in handling the primary slime from the mine. This amounted to about five tons a day with a silver content of from 100 to 150 ounces to the ton. The experiment was tried of isolating this material, and treating it in a separate concentrating circuit, but this was unsuccessful, as the final tailing from this treatment carried approximately seventy-five ounces of silver to the ton. To handle these primary slimes, a small temporary cyanide annex was installed at a low cost. This plant continued in operation for several years until the oxidized veins were worked out, and the grade of the primary slimes fell to a point where they could no longer be treated at a profit by the cyanide process.

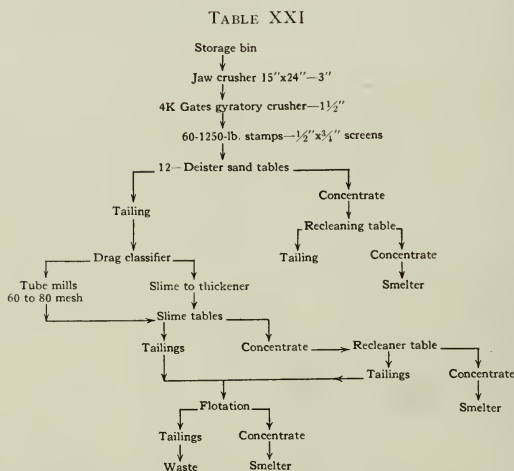
A general flow-sheet of the mill at the time the Callow flotation plant was put into operation (February 6th, 1917) was as follows:—

TABLE XX



Present Practice.—When the flotation process was first introduced in the Coniagas mill in 1917, the only change made in the flow-sheet was to eliminate the canvas tables and to send the tailing from the slime tables direct to the flotation machines. This resulted in a final slime tailing of approximately 1.5 ounces of silver to the ton. Early in 1918 two tube-mills, five feet by twenty-two feet, lined with silex and using Danish pebbles, were installed to re-grind the sand tailings to 80 mesh for further treatment by flotation. At the same time, in order to increase the stamp-duty, the battery-screens were changed from 16 mesh to 10 mesh. With the lowering of the grade of ore, it became imperative to treat an increased tonnage of low-grade rock, and maintain a high recovery, with a low working cost. The preliminary sorting and jigging treatment was now discontinued, the increased efficiency of the milling process being relied on to recover any small amount of high grade present in the ore. By using battery screens $\frac{1}{2}$ inch by $\frac{3}{4}$ inch, and substituting iron balls for pebbles in the tube-mills, the capacity of the mill was raised to 350 tons a day. The battery-discharge is given a roughing treatment on sand tables, making a low-grade concentrate which is re-cleaned, the coarse tailing going to the ball tube-mills. The ball-tube-mill discharge, after classification, together with the battery slimes is treated on slime tables, and the slime tailing sent to the flotation machines.

This process is given in outline in the following flow-sheet:—



Coniagas mill, present practice. For graphic details, see Coniagas Mines, Ltd., flow-sheet of concentration and flotation plants, page 271.

Additional Notes on Gravity Concentration

Screening Out Mine Fines.—For a time it was the practice in one mill to screen out the original mine fines, which were shipped direct to the smelter. This was later discontinued, as it was found more profitable to treat this product on tables, eliminating the low-grade rock, and producing a clean concentrate.

Skimming on the Jigs.—Owing to the small amount of valuable mineral present in the ore, it was found impossible to use a continuous discharge on the jigs. Accordingly the practice was to allow the concentrates to accumulate on the screens, and remove them periodically by skimming.

Classification of Table Feed.—The relative advantage of a close classification of the feed to the tables has been a disputed question in the Cobalt camp. In the Coniagas mill, classification before treatment on sand tables was dispensed with. The battery discharge was sent direct to the tables, the tailing being then classified into sand and slime by means of a drag classifier. The sands were sent to waste, and the slimes received a further treatment on slime and canvas tables. By this treatment it was shown that the sand tailing from an unclassified feed was as low in silver as from a closely classified one, and further, that 20 per cent. of the values in the concentrate produced by the sand tables was contained in the 200 mesh and finer sizes. In other words, on passing over the sand tables, the slime in the battery discharge was reduced 40 per cent. in silver content before receiving the final treatment on slime and canvas tables. These results are possible owing to the high specific gravity of the valuable minerals, and the ease with which they are recovered on tables. The removal, on the sand tables, of the more readily recovered values in the slime permitted of a closer adjustment in the subsequent treatment on slime tables.



Fig. 62—Shaft and mill of the Coniagas Mines, Limited.

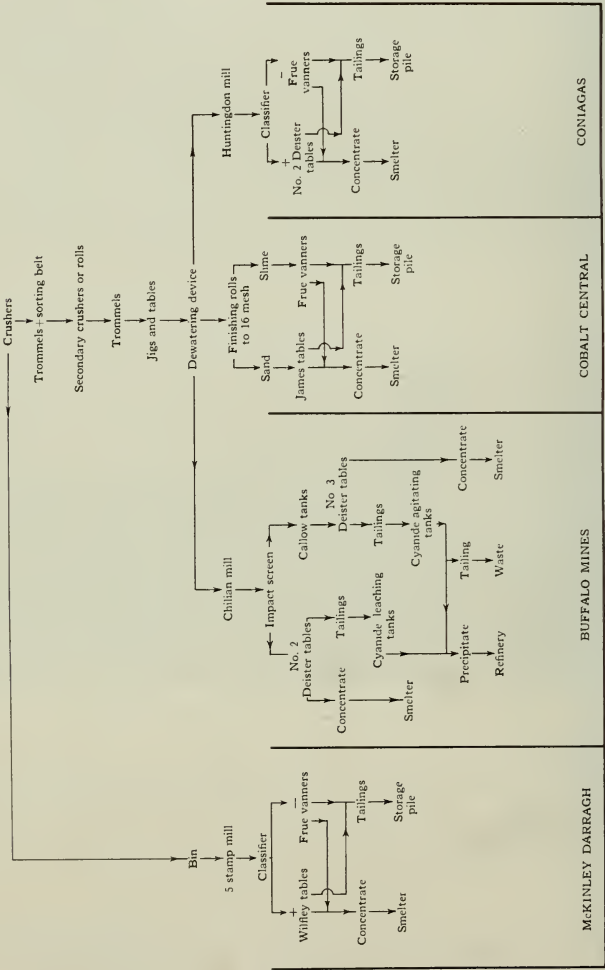
Re-cleaning Concentrates.—At most of the mills, it is the practice to make a clean tailing on the sand tables by cutting out a low-grade concentrate, which will include the free mineral, together with the true middling, and some low-grade rock. This low-grade concentrate contains about 500 ounces of silver to the ton. It is brought up to the required grade by re-treatment on cleaning-tables. This treatment produces the following products:—

- (a) A clean high-grade concentrate, containing from 1,500 to 3,000 ounces of silver to the ton.
- (b) A high-grade middling, which is returned to the cleaning-table in closed circuit, without re-grinding.

(c) A low-grade tailing, which is sent to the tube-mills for grinding and further treatment.

The following flow-sheets indicate the milling practice in operation at several of the leading mines and mills. Comparative sheets are given for the years 1907, 1914, 1917, and 1923, the last three mentioned appearing as inserts facing pages 274, 276, and 278, respectively.

TABLE XX Ia



Comparative flow-sheet, Cobalt milling practice, 1907.

The advantages of this practice are developed in the following section.

The Treatment of Middling.—A disputed question, in the treatment of ores by gravity concentration, is the disposal to be made of the inevitable middling product, as to whether or not this should be re-ground, before receiving further treatment. Both systems have been practiced in the treatment of Cobalt ores. As indicated in the preceding section, at several mills the re-grinding of the middling is not favoured, and this product is returned in closed circuit on the table used to re-clean the concentrates. From the following considerations, it is claimed that this practice will yield a higher recovery of the silver values in the ore.

In treating Cobalt ores by gravity concentration, the ratio of concentration is so high that the concentrate discharged forms only a narrow ribbon or streak on the table. The order of stratification is interesting; with minerals of the same degree of fineness, the niccolite has a tendency to ride ahead, followed in turn by fine silver, cobalt minerals, pyrite and chalcopyrite. Coarser particles of mineral on the other hand tend to come off with the middling. Owing to the narrow zone of mineral on the table, it is impossible to take off a clean concentrate without cutting a considerable amount of free mineral into the middling.

The middling thus includes both free mineral, and coarser particles of rock, together with the true middling, some of which is high in grade. The objection to re-grinding this product is the inevitable loss of silver resulting from the sliming of the free mineral present. This loss is avoided in the practice already outlined, of cutting out a low-grade concentrate, which will include the free mineral, true middling, and rock, and re-cleaning this product on a separate table. By returning the high-grade middling product to this re-treatment table without re-grinding, a zone of true middling is built up, which forms a line of demarcation between the free high-grade mineral on the one hand, and the low-grade rock on the other. This makes it possible to recover a high-grade concentrate for shipment and to eliminate a low-grade tailing, which is sent to the tube-mills for re-grinding and further treatment. The true middling continues to accumulate in the circuit until it escapes by one or another of these paths, the higher grade finally cutting into the concentrate, and the lower-grade material passing into the tailing.

Minor Developments.—Various minor developments may here be noted briefly. All varieties and combinations of riffles have been tried out, as well as tables without riffles. To replace the standard linoleum deck, various materials have been tried, including tops made of iron, monel metal, and glass. Working on unsized material, none of these were a success, as, on account of the nature of the material and the smoothness of the top, they failed to make a clean separation of ore and gangue.

Of some interest is the canvas-covered deck, used at the Nipissing low-grade mill, for concentrating in cyanide solution. The surface is of ten ounce canvas, laid on wet P. & B. paint on a wood deck. This is given two coats of P. & B. paint, before tacking on the riffles. This deck costs \$28.00 to renew and will last for one year. It handles satisfactorily a feed of 4 mesh and finer, in a solution containing 0.2 per cent. KCN and 0.25 per cent. protective alkali.

TABLE XXII.—PRODUCTION CHART OF CONIAGAS MILL FROM 1908 TO 1921

Year	Tonnage milled	Assay of heads	Assay of tailing	Ounces to waste	Low-grade concentrates recovered, tons	High-grade concentrates recovered, tons	Total concentrates recovered, tons	Silver recovered, ounces	Cost per oz. milled on oz. recovered	Smelting refining per oz. recovered	Total cost per oz. on oz. recovered
1908 (a).....	14,064	34.5	6.1	122,915	.....	.....	297.0	400,800	\$0.0753	.....	.....
1909 (b).....	19,038	37.0	5.5	107,089	.....	.....	426.0	599,975	.0652	.....	.....
1910 (c).....	33,539	33.6	5.3	182,140	.....	.....	645.5	949,901	.0427	.....	.....
1911 (d).....	52,320	36.3	4.75	241,658	.....	.....	1,418.4	1,643,616	.0351	.....	.....
1912.....	53,627	34.1	5.05	265,521	466.8	951.6	1,287.5	1,564,164	.0309	\$0.0444	\$0.0753
1913.....	54,890	28.3	4.23	228,020	484.2	803.3	1,034.3	1,323,004	.0385	.0432	.0817
1914.....	54,522	24.0	4.21	226,354	251.8	611.0	748.2	1,045,872	.0515	.0358	.0873
1915.....	55,437	23.0	3.94	208,262	155.8	496.4	629.7	1,061,621	.0492	.0325	.0817
1916 (e).....	56,973	25.7	3.99	226,119	152.4	495.5	647.9	1,250,378	.0498	.0427	.0925
1917 (f).....	60,928	18.5	2.98	178,303	260.4	482.0	742.4	1,052,303	.0874	.0431	.1305
1918 (g).....	68,597	15.9	1.75	119,305	866.8	529.5	1,396.3	828,621	.1457	.0798	.2255
1919.....	71,713	13.1	1.38	96,567	630.5	322.8	953.3	898,150	.1410	.0745	.2155
1920.....	97,634	10.2	1.43	135,488	522.8	388.6	911.4	974,670	.2397	.0735	.3132
1921.....	113,279	11.3	1.62	181,499	536.9	402.4	939.3	1,186,971	.1793	.0633	.2426
Totals.....	806,591	.....	.....	2,519,240	4,751.7	5,957.0	12,077.2	14,680,046	.....	.....	.....
Averages.....	57,614	21.17	3.12	179,946	432.0	541.5	862.6	1,048,575	\$0.1503	\$0.0400	\$0.1903

(a) Crusher rolls—Krupp & Huntington mills—changing to stamps.

(b) Thirty stamps to 20-mesh.

(c) Sixty stamps to 16-mesh.

(d) Canvas table plant put into operation January 1st, 1911.

(e) Cyanidation of primary slime from mine started February 26th, 1916.

(f) Callow flotation plant put into operation February 6th, 1917.

(g) Cyanide plant closed down November 20th, 1918—tube mills grinding all sand tailings.

Cyanidation

The early attempts to cyanide the Cobalt ores were not very successful, with the result that the first milling plants built to recover the silver values from the low-grade ores made use of the simpler process of gravity concentration. The ores of Cobalt are very complex and refractory, and their treatment by cyanidation presented a number of difficulties. Early experiments showed that the loss in the tailing was high, and the consumption of cyanide was heavy; that the working solution rapidly became foul, and lost its dissolving efficiency; and that the extraction of the silver was unsatisfactory, unless the time of treatment was unduly prolonged. These points have already been treated in some detail in the discussion on the nature of the ore. The solution of these difficulties, as a result of later research, has led to some important improvements in the treatment of complex silver ores by cyanidation. These include the development of aluminium precipitation, and the desulphurization process. Later, when it became necessary to resort to precipitation by sodium sulphide, suitable processes were developed to reduce the resulting silver sulphide to metallic silver, thus removing the chief objection to this method of precipitation. The result of these developments was to place cyanidation on an equal basis, as a competitive process, with the older treatment by gravity concentration.

Early Practice

Buffalo Mine.—Cyanidation was first used in Cobalt in 1908 in the mill at the Buffalo mine, as an accessory treatment to recover the high losses in the slime tailing. Here the ore was crushed in rolls and a Chilean mill, and separated into sands and fines on an impact screen. The sands were sent over tables, the tailing going to waste, and the slimes, after treatment on slime tables, went to the cyanide annex. The attempt was also made at the Buffalo mill to recover the values in the low-grade sand-tailing by cyanide leaching, but the experiment was not a success, and further work along this line was abandoned. Cyanidation was used also at the Nova Scotia mill (later the Dominion Reduction) in conjunction, at first, with amalgamation, and later with gravity concentration.

The O'Brien management did much of the pioneer work in developing a successful cyaniding practice, and in 1909 put into operation the first plant to treat the ore by cyanidation. In the O'Brien practice, the ore was given the usual preliminary treatment by hand-sorting and jigging, followed by a combined gravity-concentration and cyanidation treatment below the stamps. Aluminium precipitation was developed by the O'Brien metallurgists and was here used for the first time.

O'Brien Mine.—At the O'Brien, the ore was brought to the mill by a surface tram, using electric haulage, and weighed on a Fairbanks scale. It was then hand-sorted while being fed to a No. 5 Gates gyratory breaker, crushing to one and a half inches. The crushed ore was then separated into four sizes by a trommel, the coarser sizes treated on Hartz and Richards jigs, and the fines net to the stamp bins, together with the tailing from the jigs. The hand-sorted ore and jig concentrates were shipped to the smelter at Deloro. About 20 per cent. of the total mill recovery of silver was made by the preliminary treatment, most of it on the Hartz bull-jig.

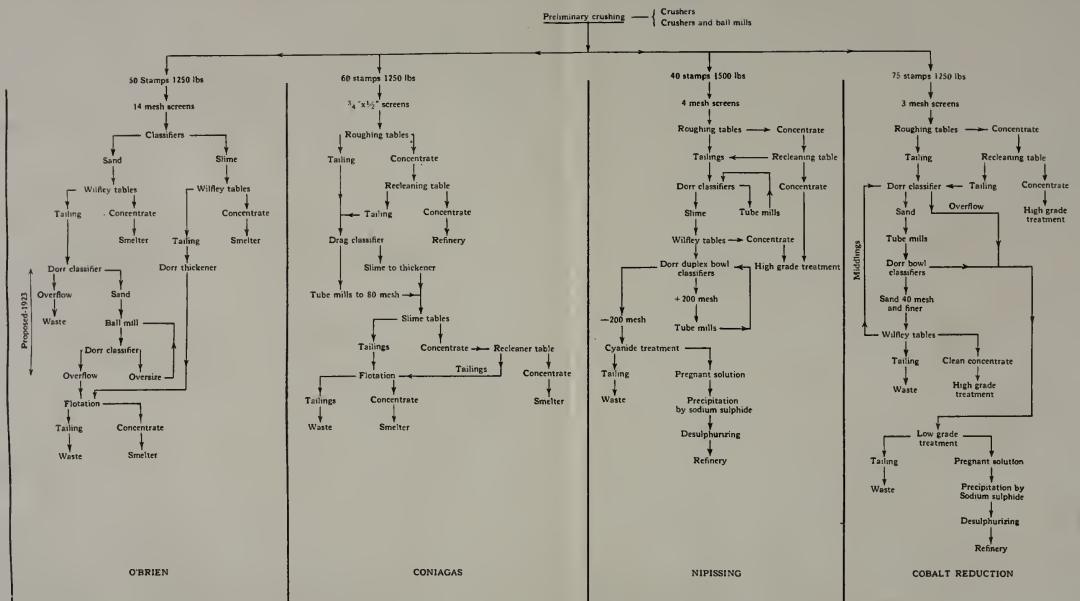
Crushing in the stamps was in a two and a half pound cyanide solution, to pass a screen with 3-mesh opening. After some earlier modifications, the practice below the stamps was as follows: The pulp was sent to a Dorr classifier, working in closed circuit with the Hardinge mills and Deister tables; about



Fig. 63—O'Brien concentrator, Cobalt.



Fig. 64—O'Brien mill, destroyed by fire, September 4, 1922.



Comparative flow-sheet, Cobalt milling practice, 1923.

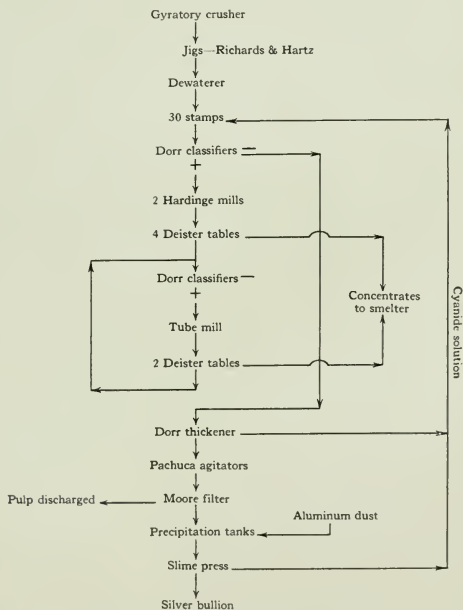
70 per cent. of the pulp, in the form of a sand, was re-ground in two Hardinge mills, and concentrated on three Deister tables, the tailing being returned to the Dorr classifier; the concentrate from the tables was shipped to the company smelter at Deloro. The table concentrate accounted for about 40 per cent. of the total recovery.

The overflow from the Dorr classifier, of which about 80 per cent. is 200 mesh and finer, passed to a 30-foot Dorr settler, and the thickened pulp was pumped to Pachuca tanks. Here the pulp was agitated for forty-eight hours in a cyanide solution made up to five pounds KCN to the ton. It was then filtered in a two-basket 24-leaf Moore filter, and the pregnant solution after clarifying was sent to the precipitating tank.

The silver was precipitated by means of aluminium dust, and the precipitate melted down without flux in a Harvey furnace, yielding a bullion about 960 fine. Later developments made it necessary to omit the preliminary jiggling treatment, to modify the crushing practice, and to use precipitation by sodium sulphide. These developments are shown in the flow-sheet of O'Brien practice (see insert facing page 276).

The earlier practice, as used at the O'Brien, is shown in skeleton outline in the following table:

TABLE XXIII



Early practice at O'Brien mill.

Nipissing Mine.—Cyanidation, as applied to the treatment of low-grade ores at the Buffalo, O'Brien, and Nova Scotia mills, was used in conjunction with

gravity concentration. The only all-cyanidation process used in Cobalt was developed in the Nipissing low-grade mill, which commenced operations in November, 1912. The outstanding features of the Nipissing practice are the fine grinding, the desulphurization treatment, and the use of aluminium precipitation. A description, in great detail, of this plant is given in J. Johnston's article, "The Mill and Metallurgical Practice of the Nipissing Mining Company," Chapter 1, *Mining and Engineering Transactions*, Vol. XLVIII, 1914, pages 3-32; and *Transactions Canadian Mining Institute*, Vol. XVII, 1914, page 64.

In brief outline, the practice used for a number of years was as follows: The ore from the various workings, after being broken to 4-inch cubes in gyratory crushers, was delivered to the mill bins, either by surface tramways or by a Bleichert aerial tram, stretching across Cobalt lake. On entering the mill, the ore was weighed on a Fairbanks registering scale, sized in a trommel, and given a preliminary treatment by hand-sorting and jigging. The concentrate was sent to the high-grade mill for treatment, and credited to the mine as high-grade ore. The rejects from the washing plant were crushed to one and a half inches in a No. 4 Gates gyratory, and sent to the stamp bins.

In the mill proper, the ore was crushed by forty stamps through a 4-mesh screen, in a 0.25 per cent. solution of caustic soda. Lime was added to the battery to the extent of five pounds per ton of ore, to facilitate settling and decantation of the clear solution back to the battery storage tank. Fine grinding was effected in a closed system of four tube-mills and classifiers, two of the tube-mills being used to grind the battery-discharge and the other two for the ultimate fine grinding. The tube-mills were six feet by twenty feet, lined with silex, and loaded with flint pebbles. Of the final product 2 per cent. remained on a 200-mesh screen, 26 per cent. to 40 per cent. being a fine —200-mesh sand, and the remainder an impalpable slime. After settling and decanting the solution, the thickened slime was sent on to the reducing treatment.

The pulp was given a preliminary desulphurizing treatment by passing it through a tube-mill, charged with ingots of aluminium. The final treatment was given by agitating the pulp by mechanical means for thirty-six hours in the filter stock-tank, which was lined with aluminium plates. After filtering, the cake carried 26 per cent. of alkaline solution as moisture, and was discharged without washing to the cyanide tanks.

Cyanidation was practised by the charge system, in mechanically agitated tanks. The pulp was agitated for forty-eight hours in a 0.25 per cent. solution of cyanide, with a dilution of 2.5 :1, the pulp was then settled, the excess solution decanted, and the thickened pulp sent to the stock-tank for filtering. A Butters' filter-plant was used. This was equipped with eighty leaves, and handled a charge of thirty-five or forty tons every three to four hours. The tailing discharged contained 26 per cent. of moisture. After being clarified, the pregnant solution was precipitated with aluminium dust. A continuous precipitation process was used, instead of the charge system, as developed at the O'Brien. The precipitate was collected in Merrill filter presses, and sent to the refinery of the high-grade mill. Here it was melted down and refined in a reverberatory furnace, the resulting bullion averaging 994 fine. The chief impurity was copper, which was brought down by the aluminium. The fineness was raised to 996 by re-melting with amalgam sponge from the high-grade treatment.

Using the practice as outlined above, the Nipissing low-grade mill had a daily capacity of about 230 tons. Working on a 26-ounce ore (below the stamps) the mill made an extraction of 92 per cent. of the silver values, actually recovered in bullion.

Ore from aerial tramway direct to washing plant bin.
Ore from surface tramway crushed to 4" and elevated to washing plant bin.
All ore crushed to 2" and elevated to battery bin.

Ore crushed to 4 mesh in batteries.
Battery pulp distributed to 12 Wilfley roughing tables.

Roughing table concentrates to re-cleaning table. Re-cleaning table concentrates to high-grade plant. Table tails to two 4'6" x 24' Dorr duplex classifiers and one 4' x 24' Dorr simplex 6' bowl classifier.

Sands from classifiers to three 20" x 6" tube mills in closed circuit with classifiers. Grinding medium pebbles.

Slime overflow from classifiers distributed to 16 Wilfley roughing tables.
Roughing table concentrates to re-cleaning table.

Tails from tables to two 4'6" x 23' Dorr duplex 15' bowl classifiers.

Sands to a 20' x 4' tube mill in closed circuit with classifiers. Grinding medium 1 1/4" iron balls.

Bowl classifier slime overflow thickened to 2.4:1 dilution in Dorr thickener.

Dorrco triplex diaphragm pump, each vat being charged with 120 tons dry ore at approximately 2.4:1 dilution, cyanide strength at start, 25 per cent KCN.

After 60 hours' treatment, pregnant solution is decanted and pulp is transferred to filter stock vat.

Filter residue discharged to tailings pond in summer and pumped to Peterson lake in winter.

Silver in pregnant solutions from both high and low-grade mills precipitated with sodium sulphide, a charge system being used with high-grade mill solution and

The resultant precipitate of silver sulphide is desulphurized in a tank 3' x 5' by being brought in

After dechlorurizing, the acetate is prepared to

After desulphurizing, the precipitate is pumped to a filter press and the soluble sulphide washed out with water.

Wet precipitate charged to an oil-fired reverberatory furnace, 6' x 5'-6" hearth, and melted to bullion.

Base bullion melted to bullion 999 fine in reverbera-

High-grade ore sampled in 6-ton lots and ground to 200-mesh in a 25' x 4' tube mill for 24 hours with 2" iron balls.

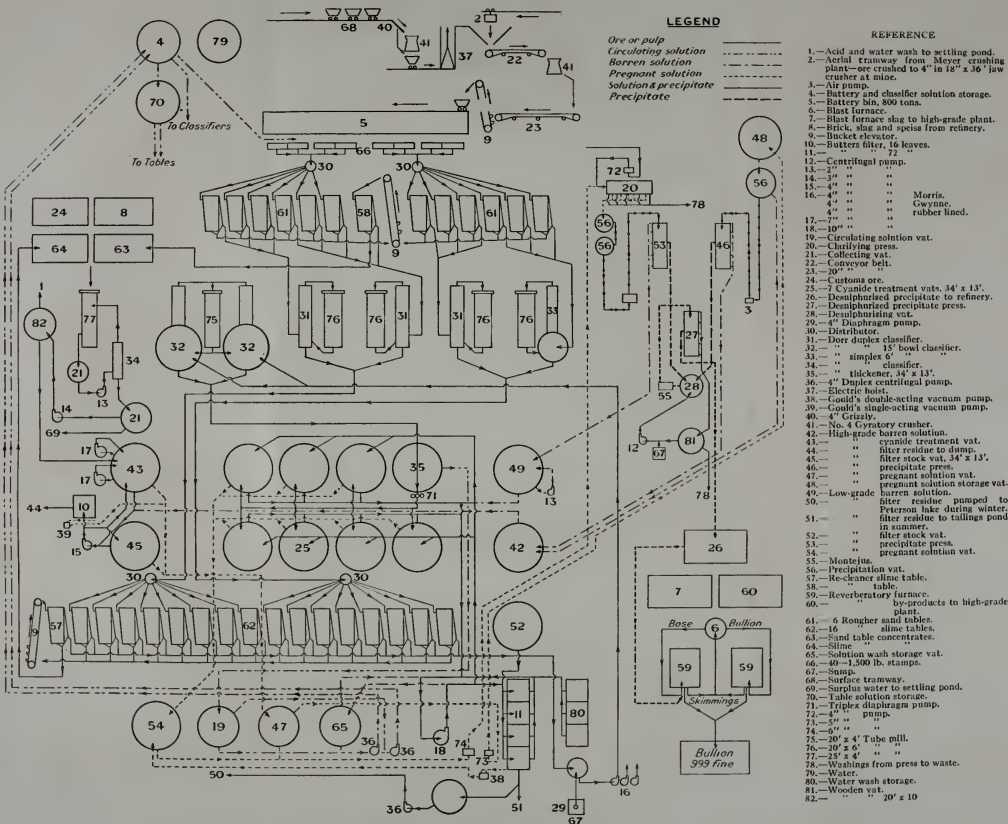
Tube mill charge is run through a Dorr simplex classifier, metallics being returned to mill and slime overflow collected for acid treatment.

A 6-ton charge at 2:1 dilution is pumped to a wooder vat, 20' x 10,' and given 10 hours agitation with 3 per cent H_2SO_4 solution. After two water washes remain-

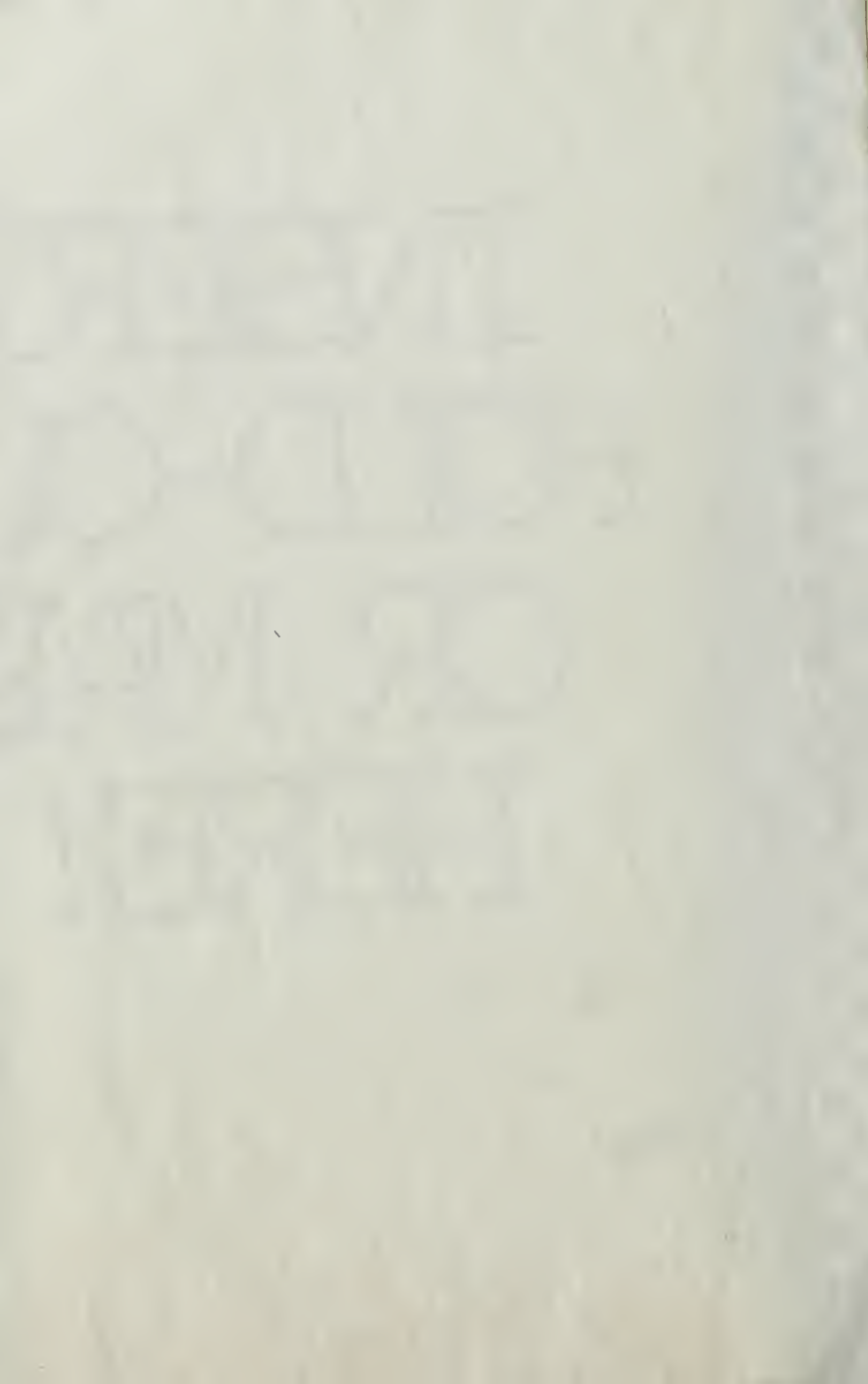
ing acid is neutralized with lime and charge transferred to cyanide treatment vat.

Charge is made up to 42:1 dilution with barrel solution, cyanide strength 0.5 per cent. KCN, and agitated for 10 hours, the charge being kept in constant circulation with two 7" centrifugal pumps.

After treatment, pregnant solution is decanted, pulp given a barren solution wash, and filtered. Residue discharged to high-grade residue dump.



Flow-sheet of low-grade mill, high-grade mill and refinery, Nipissing Mining Co., Ltd.



Development of Later Practice at Nipissing

For several years, following the commencement of operations in the latter part of 1912, the Nipissing low-grade mill continued to function satisfactorily, using the practice as outlined above. Early in 1915, however, changes in the character of the ore being treated, and economic disturbances resulting from the war, made certain changes in metallurgical treatment essential. Some of the more important of these changing conditions were as follows:—

Changes in the character of the ore: When the low-grade mill started operating, the ore carried appreciable amounts of the complex silver-minerals, which are difficult of solution in cyanide, but which yield readily to the desulphurization treatment. Later, the ore coming into the mill contained less of these minerals, until, with the increased cost of aluminium, the desulphurization treatment of the ore did not pay for itself in the increased amount of silver recovered by the subsequent treatment with cyanide.

Variations in the price of silver: Prices fell in 1915 to as low as 46½ cents an ounce, and rose later in 1919 to a maximum of \$1.37¼ an ounce.

The rise in the cost of labour and supplies, including chemicals: During the war period the cost of all chemicals was greatly enhanced, the price of aluminium dust for instance advancing from nineteen cents a pound to over \$1.00 a pound.

The development of a market for concentrates and residues containing cobalt and arsenic: During the war these base-metal by-products became a valuable source of revenue, the price of metallic cobalt advancing to \$4.50 a pound.

To meet these varying conditions the following changes were made in the metallurgical treatment of the ore.

(a) In 1915 desulphurization was discontinued, owing to the change in the character of the ore and the increased cost of aluminium.

(b) In 1916 the all-cyanidation practice was abandoned, and an experimental flotation machine was installed to ascertain whether the silver minerals, not dissolved by the cyaniding treatment, could be recovered.

(c) At the same time aluminium precipitation was abandoned in favour of precipitation with sodium sulphide. A small amount of aluminium was still used to desulphurize the precipitated silver sulphide.

(d) As experimental work on a commercial scale with the flotation process was found to be unsuccessful after cyanidation, in the latter part of 1917 the tests were discontinued and gravity concentration was installed before cyanidation.

(e) The practice of gravity concentration, with extremely fine grinding, followed by cyanidation was found to be so satisfactory that in 1921 the preliminary treatment by hand-sorting and jigging was abandoned.

Present Nipissing Practice

The various changes in metallurgical treatment, indicated above, have resulted in the present Nipissing practice, which is as follows:—

Crushing and Stamping.—The run of mine ore is crushed at the mine to 4-inch cubes in 18-inch by 36-inch jaw crushers and delivered to the mill bins by surface trams or by the Bleichert aerial tram as in previous practice. At the mill, the ore is fed over a magnetic pulley to remove tramp-iron and is reduced to 1½-inch cubes in a No. 2 Bronze Ball gyratory, before being sent to the stamp bins. Stamping is done in 0.12 per cent. KCN solution, through a 4-mesh screen.

Lime is added in the battery to the amount of five pounds per ton of ore, to facilitate settling and decantation.

Concentration and Fine Grinding.—The battery discharge is concentrated on twelve No. 6 Wilfley tables, making a low-grade concentrate, which is re-cleaned on a separate No. 6 Wilfley table. The reasons for this practice have already been given in the discussion on concentration. The tailing from the tables goes direct to Dorr duplex classifiers working in closed circuit with three 6-ft. by 20-ft. tube-mills. These are lined with hard iron and loaded with flint pebbles, and discharge a product of which approximately 8 or 10 per cent. remains on a 200-mesh screen. The classifier overflow is concentrated on sixteen No. 6 Wilfley slime tables, making a low-grade concentrate, which is re-cleaned on one No. 6 Wilfley slime table. The re-cleaning tables discharge a clean high-grade product, which is loaded at intervals into a car and conveyed to a floor where it is weighed and sampled. It is then sent to the high-grade mill for further treatment.



Fig. 65—Low-grade and high-grade mills, Nipissing Mining Company, Limited.

Final Sliming.—For final re-grinding, the tailing from the slime tables is pumped to two 15-ft. Dorr duplex bowl classifiers, operating in closed circuit with one 4-ft. by 20-ft. tube-mill, lined with hard iron and loaded to the centre with $1\frac{1}{4}$ -inch iron balls. The plus and minus 200-mesh sands are separated by the classifier, and ground in the tube-mill until reduced to an impalpable slime. The classifier overflow, containing approximately 80 per cent. of true slime, and the remainder as a very fine sand, is sent to a Dorr thickener which feeds the agitation vats.

Agitation.—The overflow from the thickener, depending on its silver content, is sent either to the circulating tank or to the precipitation supply vat. The underflow with a dilution of 2.5: 1, is pumped by a triplex diaphragm pump direct to the agitation tanks. Cyanidation is practiced by the charge system in mechanically agitated tanks. The pulp is agitated continuously for a period of fifty hours, the cyanide strength being maintained at 0.25 per cent. The oxygen necessary for dissolution is supplied by circulating the pulp by means of a 6-inch air lift, during the treatment period. The pulp is then allowed to settle

for eight hours, and the pregnant solution decanted to the precipitation storage-tank. The thickened pulp is again agitated, the depth of pulp measured, and a sample taken for calculating tonnage by specific gravity determination. The charge is then pumped to the filter storage-tank. It is interesting to note that after making due allowance for the addition of lime, pebbles, and solids in the mill solution, the calculated tonnage has checked with the weighed-in weight of this ore, over a period of eight years.

Filtering.—The pulp in the filter stock vat is agitated continuously and drawn off to the filters as required. The filter plant is arranged on a semi-gravity plan, a 10-inch centrifugal pump with hydraulically operated valves being connected with the filter-box, for handling the excess pulp and solution. A Butters filter with seventy-two leaves handles a charge of forty tons of dry slime in three and three-quarter hours. The effluent solutions are sent by means of a 12-inch by 10-inch Goulds duplex wet vacuum pump to the precipitation or circulating storage vats. The residue is flushed to the slime pond.

Precipitation and Desulphurization.—The pregnant solutions to be precipitated are delivered to a storage vat, from which they are pumped through a clarifying press in the precipitation-room by means of a 6-inch by 9-inch vertical triplex pump. The clear solution flows to the precipitation tank, where it is mixed with sodium sulphide which precipitates the silver as silver sulphide. The solution is then pumped by a 6-inch by 9-inch vertical triplex pump through a filter press, where the precipitated silver sulphide is retained. The barren solution is returned to the barren-solution tank, for further use. The silver sulphide precipitate is taken from the press every three days, and reduced to metallic silver by a desulphurizing treatment with aluminium ingots, in a solution of caustic soda. It is then sent to the refinery of the high-grade mill, where it is refined into bullion 999 fine. Details of the Nipissing practice, in precipitating, desulphurizing, and refining, are given in the discussion below.

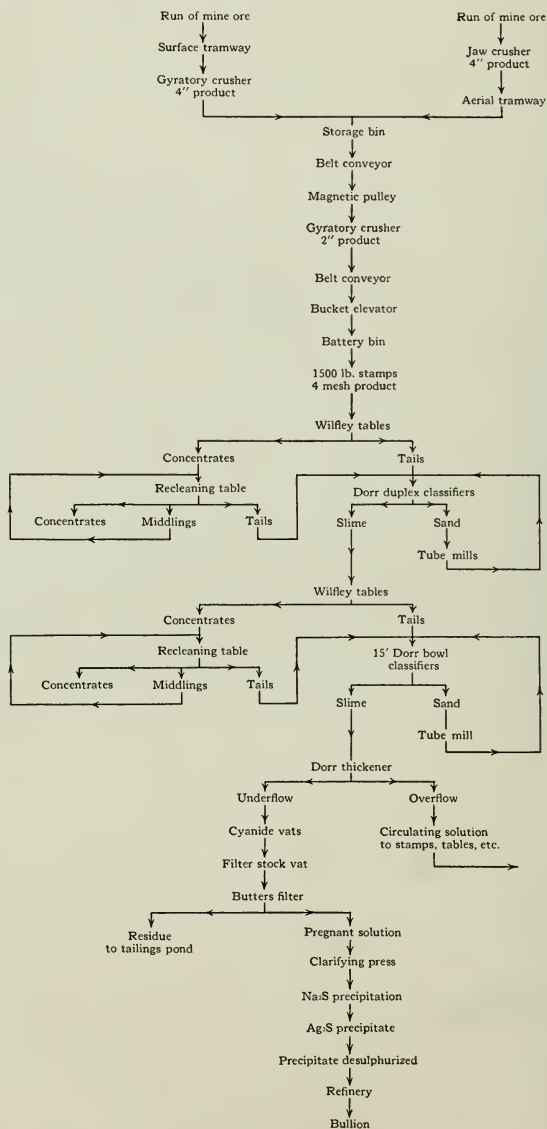
Summary of Nipissing Practice

The present Nipissing practice may be summarized as follows:—

1. Crushing run of mine ore at the mine to 4 inch in 18-inch by 36-inch jaw crushers.
2. Crushing to $1\frac{1}{2}$ -inch at mill in No. 4 gyratory crushers.
3. Stamping to 4 mesh by 40 1,500-pound stamps.
4. Roughing on Wilfley sand tables.
5. Fine-grinding in tube-mills to 8 per cent. plus 200 mesh.
6. Roughing fines on Wilfley slime tables.
7. Final sliming in tube-mill with $1\frac{1}{4}$ -inch iron balls.
8. Agitation for fifty hours in 0.25 per cent. KCN in mechanical agitators.
9. Filtering in Butters filters.
10. Sodium sulphide precipitation.
11. Desulphurizing precipitate of silver sulphide.
12. Melting and refining to bullion 999 fine.

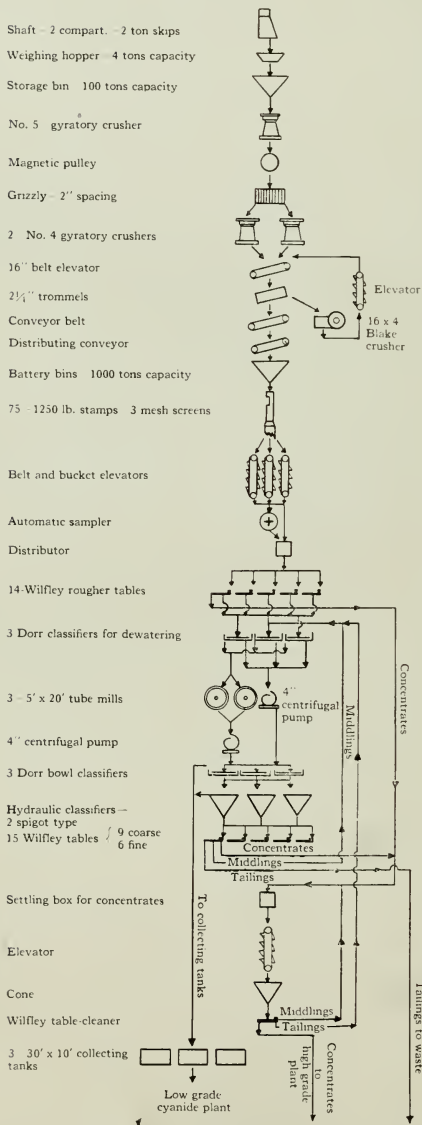
These operations are shown in skeleton outline in Table XXIV, which follows:—

TABLE XXIV



Nipissing Mining Company, Ltd., flow-sheet of low-grade mill.

TABLE XXVa



Cobalt Reduction Company flow-sheet, 300-ton plant.

Extraction.—Using the combined gravity concentration and cyanidation practice, the Nipissing low-grade mill, over a period of two years, made an extraction of 93.9 per cent., on an ore averaging approximately forty-three ounces of silver to the ton. The relative recoveries made by the different processes are shown in the following table.

TABLE XXVI.—SILVER RECOVERY AT NIPISSING LOW-GRADE MILL

Product	Total silver	Per cent. of total
	ounces	
Coarse concentrate	4,490,341.45	64.46
Fine concentrate	207,876.47	2.99
Cyanide precipitate	1,842,942.48	26.45
Loss in KCN tailing	424,915.48	6.10
Total	6,966,075.88	100.00

The low recovery in the fine concentrate is due to the dissolution of some of the silver, during the stamping and tube-milling operations.



Fig.66—Mill of the Cobalt Reduction Company.

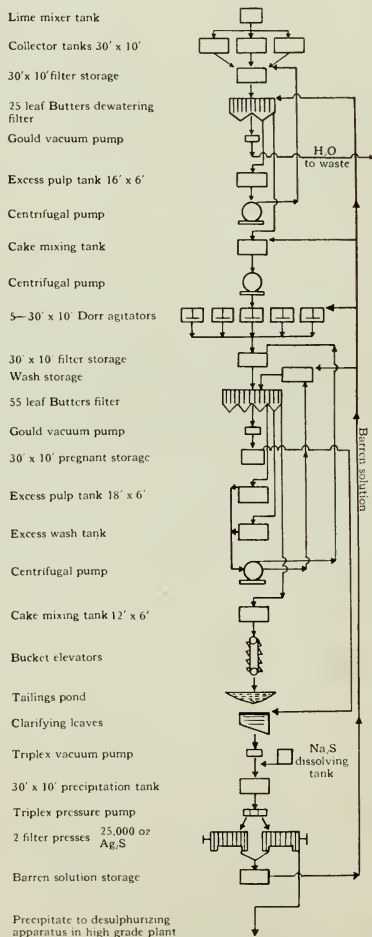
Cobalt Reduction Company Practice

The process used at the Cobalt Reduction Company mill is gravity concentration, followed by cyanidation. This is one of the best equipped mills in the camp, and since the practice offers an interesting variation from the general procedure, a brief description of this plant is given here.

Concentration.—The run-of-mine ore is delivered to the mill bins and fed to a gyratory crusher, where it is broken to 4-inch cubes. After passing over a magnetic pulley for the removal of tramp-iron, it is conveyed to a second gyratory, where it is broken to $1\frac{1}{2}$ inch. It is then delivered to the battery bins. Crushing in the battery is done with 1,250-pound stamps, in water, to pass a 6-mesh screen. The battery-discharge is sampled automatically and passed over Wilfley sand tables. The tailing is classified, the sand going direct to tube-mills, while the slime passes on to the cyanide annex. The tube-mill discharge,

now ground to 40-mesh, passes to Dorr classifiers which separate it into two products, sand and slime. The sand goes to double-spigot hydraulic classifiers which eliminate all slime, making a clean sand product. This is concentrated on Wilfley slime tables, the tailing from which goes to waste. The slime from the classifiers passes to the cyanide annex. The concentrates from all tables are re-cleaned on a separate table, making a clean product which is sent to the high-grade plant for treatment. The middling is returned to the tube-mill circuit.

TABLE XXVIa



Cobalt Reduction Company flow-sheet, cyanide annex, 190 tons capacity.

Cyanidation.—The slimes produced by the various crushing operations amount, approximately, to 55 per cent. of the original feed to mill. Ninety-eight per cent. of this material will pass a 200-mesh screen. The slime is sampled automatically, and discharged into a collecting tank equipped with a Dorr agitator mechanism. Three pounds of lime per ton of ore are added to assist settling, and the clear water is decanted to waste. The thickened pulp passes to a Butters filter plant where it is dewatered, the cake retaining 25 per cent. moisture. This is dropped into a receiving tank, barren solution is added, and the mass thoroughly agitated. It is then pumped to Dorr agitators and given a cyanide treatment at a dilution of 2:1 for a period of fifty-five hours. The cyanide strength is maintained at 0.25 per cent. KCN. After treatment the pulp passes to a storage tank, which feeds the Butters filter. After filtering, the cake is washed with barren solution, and discharged to waste. The pregnant solution is clarified by vacuum filters, and the silver precipitated by the charge-system with sodium sulphide, the precipitate being desulphurized with aluminium. The precipitation practice is similar to that of the Nipissing which is described later.

Summary.—The points of greatest interest in the Cobalt Reduction Company practice are:—

1. Concentration in water.
2. Separation of sand from slime—45 per cent. of the total feed is ground to 40 mesh and concentrated, the tailing going to waste; 55 per cent. of the total feed, ground to 200 mesh, is treated by cyanidation
3. Treatment of high-grade ore and table concentrates by the hypochlorite cyanidation process. This plant is described in a later section discussing the treatment of high-grade ore.

Recovery.—The results obtained at the Cobalt Reduction Company's plant are shown in the following table:—

TABLE XXVII.—PRODUCTION CHART OF COBALT REDUCTION COMPANY

Schedule	Years 1917 and 1918	Per cent.	July 1, 1921, to June 30, 1922	Per cent.
Tons treated	125,845	.....	96,509	.....
Average assay, oz. per ton	38.53	.....	18.07	.....
Ounces contained	4,849,077	.....	1,743,949	.....
Tons concentrate	1,847.74	.....	656.90	.....
Average assay, oz. per ton	2,021.17	.....	1,729.87	.....
Ounces contained	3,734,603	77.02	1,136,351	65.16
Tons cyanided	70,952	.....	51,729	.....
Average assay, oz. per ton	13.23	.....	9.21	.....
Ounces contained	939,046	.....	476,485	.....
Ounces recovered	775,320	15.99	376,966	21.62
Total ounces recovered	4,509,923	93.01	1,513,317	86.78
Tailing (ounces)	339,154	6.99	230,632	13.22

Additional Notes

Dissolution.—Extremely fine grinding of the ore is essential to dissolution of the silver values in a reasonable time of treatment. The failure to appreciate

this fact was one of the principal reasons for the poor extraction obtained in some of the earlier work. The degree of comminution required varies with the amount of antimony present. Metallic silver containing antimony dissolves very slowly in cyanide solution, as do also the complex silver-minerals, unless they are ground very fine.

The ore is strongly reducing. This is due to the presence of soluble compounds of sulphur, arsenic, and antimony, e.g., sulphides, arsenites, antimonites, etc. These soluble compounds are oxidized to thiosulphates, arsenates, and antimonates, etc., by the dissolved oxygen, with the result that the dissolving efficiency of the solution is greatly impaired. A large amount of air must be supplied to prevent the solution being robbed of its dissolved oxygen.

Desulphurization.—The object of this treatment was to decompose the complex silver-minerals into their respective elements, leaving the silver in a spongy metallic state, in which condition it was readily amenable to cyanide treatment. This was accomplished by bringing the ore into direct contact with aluminium in a solution of caustic soda. The method of applying this treatment, in actual operations, has already been given in the discussion of earlier Nipissing practice. A complete description of the process is given in the paper by J. J. Denny, "Desulphurizing Silver Ores at Cobalt," *Mining and Scientific Press*, September 27th, 1913.

At the Nipissing low-grade mill, desulphurization was practised for several years. It was discontinued in 1915, when the change in the nature of the ore and the increased cost of aluminium rendered it commercially ineffective. Desulphurization is still used in the reduction to metallic silver of the silver sulphide resulting from sodium sulphide precipitation. This is discussed below.

Costs and Extraction.—In the early Nipissing practice, desulphurization of the ore then being treated resulted in an increased extraction of one to four ounces of silver, at the cost of one ounce. Detailed costs of treatment, taken from the article by J. J. Denny, already referred to, are given in the following table:—

TABLE XXVIII.—COST OF DESULPHURIZING TREATMENT

Collecting, desulphurizing, and transferring of pulp:—

Labour.....		Per ton
Supplies—Aluminium.....	0.81 lb.	\$0.050
Caustic soda.....	1.4 "	0.347
Lime.....	5. "	
Power.....		0.027
Workshop.....		0.008
Total.....		\$0.432

Alkali solution, filtering and transferring:—

Labour.....	Per ton
Supplies.....	\$0.069
Power.....	0.006
Workshop.....	0.028
Total.....	0.002
Total.....	\$0.105
Total cost of treatment.....	0.537

Agitation.—Agitation during the cyanidation treatment is carried on in tanks of various forms and designs. These include the Dorr agitator, Pachuca tanks, and agitators of the mechanical stirrer type. Of these the Dorr agitator is considered the most satisfactory, owing to its simplicity, low power consump-

tion, and the absence of mechanical trouble. In the cyanidation of these ores a high dilution is desirable, the treatment of 20-ounce ore requiring a dilution of 2:1 or more. Since subsequent settling and decantation of the clear solution is not possible, a high dilution cannot be used in the Pachuca tank without throwing a heavy load on the filtering plant.

Filters and Filter Presses.—Vacuum filters of the Butters and Moore type are used in all the mills. The Dominion Reduction and the O'Brien mills use the Moore filter. The Butters filter is used at the Nipissing and Cobalt Reduction plants.

The filtering cycle of the Nipissing low-grade mill, shown in the following table, is indicative of the general practice.

TABLE XXIX.—FILTERING CYCLE AT THE NIPISSING LOW-GRADE MILL

	Minutes
Filling filter box with stock pulp.....	5
Period vacuum applied.....	60
Pumping back excess pulp.....	8
Pumping in solution wash.....	6
Time washing.....	90
Pumping back solution wash.....	6
Pumping in water wash.....	6
Time water washing.....	18
Pumping back water wash.....	6
Discharging residues.....	20
Total time of filtering cycle.....	3 hrs. 45 min.
Thickness of cake.....	1¾ in.
Specific gravity of pulp.....	1.3
Tons of dry slime filtered.....	40

The filter presses used are of various designs. The Nipissing and Dominion Reduction use the regular Merrill triangular filter press for clarifying the solution and collecting the precipitate. The Cobalt Reduction use the Perrin press. The O'Brien used a Perrin press for clarifying, and a Schriver press for collecting the precipitate. Between these various machines there is little choice; all operate on the same mechanical principle, and give equally satisfactory results.

Precipitation

Three distinct methods for precipitating silver have been used in the cyanidation of Cobalt ores. These are:—

1. Precipitation with zinc,
2. Precipitation with aluminium,
3. Precipitation with sodium sulphide.

Precipitation with zinc.—At the Buffalo mill precipitation was effected by zinc-shavings, using three wooden boxes of the ordinary type. At the Dominion Reduction mill, zinc dust was used, with a regular Merrill triangular filter press for collecting the precipitate. The Nipissing low-grade mill was originally designed for precipitation with zinc dust, but after investigation the system of precipitating with aluminium was adopted before the mill started to operate.

The use of zinc as a precipitant, in a solution containing appreciable amounts of arsenic and antimony, was found to be very unsatisfactory. In addition to causing a heavy consumption of cyanide, the zinc fouled the solution, resulting in a marked decrease in dissolving efficiency. A comparison of zinc with aluminium, as a precipitant of silver from cyanide solution, is given in the following discussion.

Aluminium Precipitation.—Precipitation by aluminium was developed by S. F. Kirkpatrick, who applied it in a commercial way to the cyanidation of Cobalt ores, first at the Deloro smelter, and later at the O'Brien mill in Cobalt. Its advantages over precipitation by zinc were later fully investigated by the metallurgists at the Nipissing before its adoption in the low-grade mill. The subject is covered fully in the articles by J. J. Denny¹, E. M. Hamilton², and S. F. Kirkpatrick³. Details of the practice used at the Nipissing and O'Brien mills are given in E. M. Hamilton's article.

The advantages of aluminium precipitation are as follows:—

(1) No fouling of the solution, and no loss of dissolving efficiency, but rather the reverse. The working-solution showed an increased dissolving power of 0.35 ounces of silver per ton of ore, over a freshly made solution.

(2) A regeneration of cyanide, instead of a heavy consumption. Unlike zinc, aluminium forms no cyanogen compound, and in addition actually regenerates the cyanide combined with the silver. In the Nipissing mill, this regeneration amounted to 0.608 lbs. of KCN per ton of solution, or 1.67 lbs. of cyanide per ton of ore treated, equal to 408 lbs. of cyanide a day.

(3) The recovery of the silver as a clean high-grade precipitate, averaging 27,000 ounces to the ton, or about 930 fine. The barren solution is reduced to about 0.05 ounces of silver to the ton.

Cost of Aluminium Precipitation.—The following data showing the relative costs of precipitation by aluminium and zinc are taken from the article by E. M. Hamilton, already referred to.

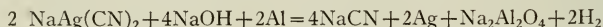
The present price of aluminium dust, laid down at the Nipissing, is 38 cents per pound, and of zinc dust 7 cents per pound. The consumption of aluminium is 0.02 pound, and of zinc dust 0.1 pound, per ounce of silver precipitated, on an ore yielding 20 ounces of silver to the ton. The relative costs would be as follows:—

TABLE XXX.—COMPARATIVE COSTS OF ZINC AND ALUMINIUM PRECIPITATION

Aluminium dust		Zinc dust	
0.4 pound aluminium at 38 cents.....	\$0.152	2 pound at 7 cents.....	\$0.14
1.5 pound caustic soda, 2¼ cents.....	0.033		
Per ton.....	\$0.185		\$0.14

In the figure for caustic soda, 0.5 pounds has been allowed for chemical consumption and 1 pound for mechanical loss. To offset the extra charge of 4½ cents per ton of ore, there would be a direct recovery of 9.6 pounds of KCN at 15 cents or \$0.24 per ton; a further saving in cyanide due to the absence of any action between the precipitant and the cyanide; a saving in the cost of milling and refining, and in some cases, of marketing the bullion. In addition there is a gain in extraction of from 7 per cent. to 14 per cent.

The equations given for the precipitation of silver by aluminium are as follows:—



According to this equation, one part of aluminium would precipitate four times its weight of silver. In practice, the proportion is found to be about three of silver for one of aluminium.

Analysis of Precipitate.—The following tables give analyses of the precipitates obtained at the Nipissing and Dominion Reduction mills:—

¹J. J. Denny, Mining and Scientific Press, September 27th, 1913.

²E. M. Hamilton, Engineering and Mining Journal, May 10th, 1913.

³S. F. Kirkpatrick, Engineering and Mining Journal, June 28th, 1913.

TABLE XXXI.—ANALYSIS OF SILVER PRECIPITATE BY ALUMINIUM DUST AT NIPISSING MILL

	Per cent.
Silver.....	89.92
Sulphur.....	0.84
Lime.....	1.07
Iron.....	0.95
Mercury.....	0.48
Aluminium.....	0.56
Copper.....	0.36
Arsenic.....	0.48
Antimony.....	0.64
Nickel.....	0.16
Lead.....	0.08
Bismuth.....	0.03
Zinc.....	0.06
Cobalt.....	trace
Silica and insoluble.....	2.98

TABLE XXXII.—ANALYSIS OF SILVER PRECIPITATE BY ALUMINIUM DUST AT DOMINION REDUCTION COMPANY MILL

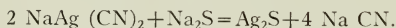
	Per cent.
Silver.....	88.04
Silica.....	3.50
Copper.....	0.78
Iron.....	1.84
Cobalt.....	0.13
Nickel.....	0.16
Aluminium.....	0.84
Lime—CaO.....	1.04
Arsenic.....	2.41
Lead.....	0.65
Sulphur.....	0.27
	99.30

Sodium Sulphide Precipitation.—The present practice of precipitation by sodium sulphide was developed in 1916 at the Nipissing mill, to replace aluminium precipitation, and like the former practice, it soon became general in the camp. The change was made urgently necessary as a result of the changes in economic conditions wrought by the war. Before the war, aluminium dust cost 33.82 cents per pound and caustic soda 2.11 cents per pound, laid down at the mine. In May, 1916, the price of aluminium dust was advanced to 90 cents, and caustic soda to 5.77 cents per pound. At these prices, the increased cost of these two chemicals amounted to about \$33,000 a year. Although developed to meet an emergency, the present practice has been so satisfactory that it will be permanently retained. A complete description of the process and the Nipissing practice is given in the article by R. B. Watson, "Sodium Sulphide Precipitation of Silver at the Nipissing Mine," Transactions of the Canadian Mining Institute, Vol. XX, 1917, from which are taken many of the data here given.

The sodium sulphide process involves the precipitation of the silver as silver sulphide, the reduction of the precipitate to metallic silver by a desulphurizing treatment, and the melting down of the resulting silver to fine bullion.

At the Nipissing, precipitation is effected in two wooden tanks, 5 ft. by 6 ft., provided with mechanical agitation. In the first tank the clarified solution meets a small stream of concentrated sodium sulphide, which throws down the silver sulphide as a fine precipitate. To avoid blinding the canvas, the precipitate is caused to agglomerate by agitating it in the second tank, before it is drawn off to the filter press. In practice it is found that 0.06 lbs. of sodium sulphide (60 per cent. strength) are required to precipitate one troy ounce of silver. Gold is not precipitated at all, nor is copper, if the solution contains

not less than 0.15 per cent. of free cyanide. As with aluminium, precipitation by sodium sulphide regenerates all the cyanide combined with the silver in the pregnant solution. The reactions involved are shown in the equation:—



A press full of sulphide precipitate contains about 23,000 ounces of silver.

Treatment of Precipitate

O'Brien Practice.—To reduce the precipitate of silver sulphide to metallic silver, several processes were developed at the O'Brien mill. These are, briefly, as follows:—

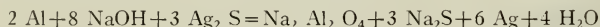
(1) The precipitate was melted and cast into anodes which were electrolysed in a solution of caustic soda, using carbon cathodes.

(2) The silver sulphide was melted in crucibles with scrap iron, yielding a base bullion and an iron matte, which carried appreciable amounts of silver. These were shipped to the company's smelter at Deloro.

(3) The latest practice, used up to the time of the destruction of the mill by fire (Sept., 1922), was to fuse the silver sulphide with aluminium ingots in a Harvey tilting furnace. By this treatment one pound of aluminium will refine twelve pounds of silver, yielding a bullion up to 980 fine, and a slag of aluminium sulphide; 5 per cent. of the silver enters the slag. About four tons of slag are accumulated in a year, from the treatment of about 250,000 ounces of silver.

Nipissing Practice.—At the Nipissing, the precipitate is reduced to metallic silver by a modified form of the desulphurizing process, already described in the treatment of the ore.

The precipitate of silver sulphide is transferred to an iron tank 7 ft. by 5 ft., provided with a mechanical agitator. Aluminium ingots, weighing 500 lbs., are thrown in, and caustic soda is added, about 0.03 lbs. of 76 per cent. caustic soda being required for every ounce of silver. With a dilution of 4:1 the solution has a strength of about 8 per cent. NaOH. The mixture is agitated until the black silver sulphide turns brown. This requires about eight hours, depending upon the temperature of the solution. The caustic solution must not be too hot, as the reaction with the aluminium will then become too violent. This will interfere with the reduction of the silver sulphide, as the large amount of hydrogen given off prevents the actual contact necessary between the sulphide and the aluminium. The desulphurized precipitate is collected in a filter press, washed free of sodium sulphide, and delivered to the refinery. The ingots remaining are left in the bottom of the tank for the next charge. The reactions involved are shown in the following equation:—



Samples taken of the silver sulphide precipitate, before and after treatment, are assayed for silver. The increase in silver after desulphurizing is approximately 3,000 ounces. If the pregnant solution is well clarified before precipitation, it is possible to make a product, after desulphurizing, that will assay 27,000 ounces. Analyses of the precipitate, before and after desulphurizing, are given in the following table, from the article by R. B. Watson, already referred to.

TABLE XXXIII.—ANALYSIS OF SILVER SULPHIDE PRECIPITATE, BEFORE AND AFTER DESULPHURIZING

	Before desulphurizing per cent.	After desulphurizing per cent.
Ag.....	81.21	91.72
S.....	12.09	0.58
Soluble in water.....	2.02	0.52
Insoluble in acid.....	2.63	3.03
FeO.....	0.46	0.57
Al ₂ O ₃	1.32	1.55
CaO.....	0.44	0.49
MgO.....	0.14	0.16
Hg.....	0.10	0.11
	100.41	98.73

The precipitate contains no Au, Cu, Bi, Co, Ni, or Zn.

Refinery.—The desulphurized precipitate is weighed in lots, as received from the mill, and samples taken to determine the moisture and silver content. It is then charged to the reverberatory refinery furnace and melted down without flux, yielding a bullion 999 fine. During the refining the impurities are skimmed off by the operator, with a rake. These skimmings are accumulated from one to two months and melted down in a small blast furnace. The resulting base bullion is melted down with the next lot of precipitate. The slag from the blast furnace is weighed and assayed for silver and delivered to the high-grade mill, where it is given the same treatment as the concentrates. The time required for refining approximately 35,000 ounces varies from twenty-four to thirty-six hours. The fine bullion is ladled from the furnace and cast in iron moulds, to bars of about 1,200 troy ounces.

Treatment of Skimmings.—From forty-three lots of precipitate, charged to the reverberatory furnace, the following table shows the silver content of the various products from the treatment of the skimmings in the blast furnace.

TABLE XXXIV.—SILVER CONTENT OF PRODUCTS FROM SKIMMINGS TREATED IN BLAST FURNACE

		Silver content
Total weight of precipitate melted and refined in reverberatory furnace.....	66,308 pounds	832,308.57 oz.
Skimmings produced.....	8,947 “	52,721.84 “
Skimmings by weight.....	13.49 per cent.	6.33 per cent.
Silver content of skimmings.....		40.42 “
Slag and speiss produced in blast furnace.....	4,020 pounds	1,991.06 oz.
Slag and speiss produced in blast furnace by weight.....	6.06 per cent.	0.24 per cent.

Owing to the richness of the skimmings, practically no flux need be added for smelting. The furnace charge is made up by mixing the skimmings with about 15 per cent. by weight of coke and a small amount of speiss, which acts as a wash. The products from the furnace are slag, speiss, and a base bullion which assays about 850 fine.

Annual Clean-up.—The reverberatory furnace is in practically continuous operation for one year, very little patching being required to keep it in good shape. At the end of the year it is broken down and re-built, in order to make the annual clean-up. After treating between three and four million ounces of silver during the year, the amount of silver recovered from the brick and pan-bottom is less than 2 per cent. Over a period of three years, the consumption of fuel oil for 1,000 ounces of refined silver bullion was 11.5 gallons.

Sampling Milling Ore

At the Nipissing mill the ore is sampled by hand by taking samples of the stamp-battery discharge every half-hour over a period of twenty-four hours.

When grinding in cyanide solution containing dissolved silver, this system of sampling is not accurate, in spite of corrections for dilution and solution assay. Errors are due both to dissolution of silver by the cyanide solution in the battery, and to re-precipitation of dissolved silver by the action of cyanicides present in the ore. On treating clean ore, about three ounces of silver are dissolved in the battery and the recovery is higher, by this amount, than the amount of silver indicated by the heads. Re-precipitation of the dissolved silver is caused especially by decomposed nickel minerals. At one time it was thought that carbon might be the offender, as some ores contain carbonaceous slates, but a few tests showed that the material does not act as a precipitant of silver from cyanide solutions. On treating ores containing decomposed nickel minerals, about three ounces of silver are re-precipitated in the battery. Under these conditions the heads appear to be high and the extraction of silver low. The range of error is thus about six ounces in a 45-ounce head sample.

Sampling of Table Concentrates

The results from the sampling of table concentrates at the Nipissing Mill are interesting. The following figures show the comparative results of sampling by hand and mechanically, a total weight of 3,652 tons of wet table concentrates, containing 7 per cent. moisture. Hand sampling was carried out by quartering lots of six tons before charging into a 4 ft. by 25 ft. tube-mill. The feed was ground for twenty-three hours with iron balls, at a dilution of 1:1, to pass a 200-mesh screen. It was then dumped into a tank where it was diluted to 7:1 with water, and classified. The classifier overflow was sampled by an Elmore sampler located in the launder, twelve feet from the classifier. The pulp was sampled by another automatic sampling device, which cut samples from the launder as the pulp was discharged into a receiving tank. The results are shown in the following table:—

TABLE XXXV.—SAMPLING WET TABLE CONCENTRATES BY HAND AND ALSO AUTOMATICALLY		
Quartering method (4-mesh product).....	Oz. per ton	1362.95
Automatic method (200-mesh product) (after allowing for dilution by foreign matter).....	Oz. per ton	1262.19
Difference in favour of quartering method.....	100.76 oz.	7.39 per cent.

The silver, recovered as fine bullion, checked with the quartering method.

Aero-Brand Cyanide

Aero-brand cyanide was used in the camp for three years. During this time it did good work and showed a saving over 98 per cent. sodium cyanide, which was then selling at an advanced price. Aero-brand cyanide is high in lime, which it was found necessary to eliminate by adding soda ash to the mill solution. In the treatment of Cobalt ores a high lime is objectionable, as it has a tendency to retard the activity of the solution, with a consequent decrease in the extraction of silver. This effect is due either to the increased viscosity of the solution, which interferes with the migration of the ions, or to the reaction of CaO with some other compound in the solution.

As 98 per cent. sodium cyanide is easier to handle, the use of Aero-brand cyanide was discontinued when, as a result of declining price, the cost of Aero-brand, together with the soda ash, showed no advantage over the 98 per cent. product. Aero-brand does good work elsewhere, when used with zinc precipitation, owing to the precipitation of the lime as calcium zincate. Carbon dioxide from the atmosphere also precipitates some of the lime as calcium carbonate. Comparative analyses of the barren working-solutions from the treatment of these ores by 98 per cent. sodium cyanide and Aero-brand cyanide, are shown in the following table:—

TABLE XXXVI.—COMPARATIVE ANALYSIS OF BARREN WORKING-SOLUTIONS, USING 98 PER CENT. SODIUM AND AERO-BRAND CYANIDE

Analysis made January 20, 1916, NaCN and Al dust precipitation.		Analysis made May 14, 1920, on high and low-grade solution using Aero-brand cyanide and sodium sulphide precipitation.	
	Low-grade solution		High-grade solution
Specific gravity.....	1.007	Specific gravity.....	1.0571
	Per cent.		Per cent.
Total solids.....	1.190	Total solids.....	8.304
Free KCN.....	0.212	Total cyanogen.....	1.13
Total KCN.....	0.303	Free cyanide (KCN).....	0.47
Alkali.....	0.180	Alkali before removing CO ₂ ..	1.33
KCNs.....	0.080	Alkali after removing CO ₂ ..	0.89
Cu.....	0.060	Lime (CaO).....	0.04
Ni and Co.....	0.010	Fe.....	0.03
Al.....	0.020	Ferrocyanide.....	0.18
Fe.....	0.001	Thiocyanate.....	0.12
As.....	0.050	Chlorine.....	1.44
Sb.....	0.040	Cu.....	0.31
CaO.....	0.016	Ni and Co.....	0.04
		Magnesia.....	0.01
		Sodium.....	1.96
		Silver.....	.80 oz.
		Carbon (floating or in suspension).....	none
			.28 oz.

The Flotation Process

Introduction

Various small scale tests were made with the Flotation Process in Cobalt prior to 1915, but the results of these were largely unsatisfactory. One of the principal difficulties was that the concentrates produced were low in grade, assaying only from thirty to fifty ounces of silver to the ton. Unfortunately no attempt was made to re-clean these low-grade concentrates, as otherwise a satisfactory process might possibly have been developed sooner.

In October, 1915, the Buffalo Mines, Limited, built an experimental flotation plant, capable of working on a tonnage scale. The machines used were of the Callow pneumatic type. The experimental work in this pioneer plant was under the direct personal supervision of J. M. Callow, who furnished experienced operators to take charge of the work. The treble-length Callow cell was here developed to meet local conditions, since, to obtain the best results, the Cobalt ores require a relatively long treatment. The adaptation of the flotation process to the treatment of the Cobalt ores was a direct result of the research work carried on at the Buffalo experimental plant.

The following September, the Buffalo Mines began to operate a Callow flotation plant, having a daily capacity of 600 tons, treating the current tailing from the gravity concentration plant, in addition to re-treating a large tonnage of similar tailings that had accumulated on the property.

The success of these plants soon led to the general adoption of this process and similar plants were built by the McKinley-Darragh-Savage Mines, the Coniagas Mines, The Dominion Reduction Company, the Northern Customs Concentrator, and the National Mines. In addition to these an experimental plant was operated by the Nipissing Mines over a period of one year, to determine whether the process could be used to advantage for the re-treatment of the tailings from the cyanide plant. The combined daily capacity of these plants was, approximately, 2,000 tons.

General Outline of Cobalt Practice

Oil Mixtures.—The flotation plants in Cobalt use an oil mixture of pine oil, coal tar creosote, and coal tar. This mixture, in the proportions of 15 per

cent. pine oil, 75 per cent. coal tar creosote, and 10 per cent. coal tar, was adopted as a result of the research work done at the Buffalo experimental mill, and with variations in the amounts of pine oil and creosote, has been used by all the other mills. Many other oils and mixtures of oils have been tried, both in the laboratory and in large scale tests under mill conditions, but this particular combination has been found to be the most satisfactory. At the Coniagas mill it has been found good practice to sulphidize the oil mixture by distilling it under pressure with sulphur. The proportions used are 25 per cent. of No. 350 pine oil, 65 per cent. creosote, and 10 per cent. coal tar, together with $2\frac{1}{2}$ per cent. sulphur. The oil mixture is added to the tube-mill in amounts varying from $\frac{3}{4}$ to $1\frac{1}{2}$ lbs. per ton of ore treated. The amount of oil required will vary with the dilution of the pulp, the amount of mineral present, the fineness of the product being treated, and the skill of the operator.

Concentration and Grinding.—It may be said in general that the silver content of the tailing from the flotation process varies directly with the value of the feed to the cell. For this reason it has been found good practice to recover as much of the silver as possible by gravity concentration, before treatment by flotation. The tailings from the preliminary concentration treatment are ground in tube-mills, usually to 80 to 100 mesh, depending on the character of the ore. At the Coniagas mines, the practice is to grind to pass to 60-mesh screen. The oil mixture is added in the tube-mill, as a thorough emulsification of the oil is essential to good results. Care is taken also to screen out all chips and wood-pulp, as this material is found to interfere seriously with successful work. After grinding, the ore is given a final concentration on slime tables, before passing to Dorr thickeners or Callow cones. The thickened pulp is then pumped either to a mechanical mixer, where it receives an additional oiling, or direct to the flotation cells. The overflow from the thickeners is practically clear water. This is either discarded or is pumped back to be used over again in the circuit.

The Flotation Cells.—The treble-length Callow pneumatic cell, either single or double compartment, is used throughout the camp as a roughing cell. These are twenty-seven feet long and twenty-four inches wide, and are supplied with air at from four to six pounds pressure. The dilution of the feed is from 3 to 5:1, a low dilution being necessary to yield a low tailing. The rougher cell discharges a low-grade concentrate, assaying about fifty ounces of silver to the ton, which goes to the cleaner cells, and a tailing, assaying from one to two ounces of silver to the ton, which is sent to waste.

The cleaner cell is a single length Callow pneumatic cell 9 ft. by 24 inches, similar in detail to the rougher cell. The concentrate from the rougher cell is treated at a dilution usually from 15 to 20:1, without any further addition of oil. The high dilution is required to make a high-grade concentrate. A device, commonly adopted to assist in raising the grade of the concentrate, is to build up the sides of the cell to within six inches of the lower end, in order to restrict the overflow. It has also been found by some operators that, by adding sodium carbonate or sodium silicate to the cleaner cell circuit, a much higher grade of concentrates can be produced. The final concentrate usually assays from 300 to 600 ounces of silver to the ton.

Treatment of the Middling.—The tailing from the cleaner cell is called the middling. This material is not a true middling, but consists largely of a mixture of oiled particles of free mineral and rock matter, together with the true middling. It amounts to approximately 8 per cent. of the original feed, and assays from ten to thirty ounces of silver to the ton, varying with the grade of

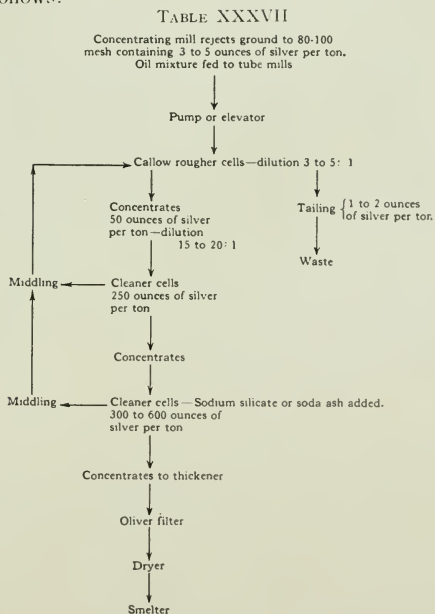
the current ore. The treatment of this product is a disputed question and has led to a considerable variation in practice. Some operators treat it by the cyanide process, others re-clean it several times in a separate circuit and finally discard a tailing containing from three to five ounces of silver to the ton, which joins the tailing from the roughing cells; others again return the middling to the head of the rougher cells with the chance of lowering its silver content before it is finally discarded with the tailing from the rougher cells. The objection to the latter course is that the high dilution of the middling disturbs the control of the rougher cell, where a low dilution is essential to the production of a low tailing. Hence the advantage of cyaniding this product or of treating it in a separate circuit.

Treatment of Concentrate.—The general practice is to settle the concentrates in Dorr thickeners, filter the thickened discharge on Oliver continuous filters, and finally dry on steam coils. The product, still carrying 5 per cent. moisture, is bagged and shipped to the smelter.

Summary.—The points essential for the best results in floating the Cobalt ores are as follows:—

1. The removal of as much of the value as possible by gravity concentration.
2. The emulsification of the oil in the tube-mill.
3. The removal of chips and wood pulp.
4. A low dilution—3:1—in the rougher cell in order to get a low tailing.
5. A high dilution—15 to 20:1—in the cleaner cell to get a high-grade concentrate.

A skeleton flow-sheet of the mills using gravity concentration, followed by flotation, is as follows:—



Flotation flow-sheet of general practice.

The Coniagas Practice

The details of the froth flotation process, as applied to the concentration of Cobalt ores, are well exemplified in the following description of the practice used at the Coniagas plant.

Concentration and Grinding.—The battery discharge, without classification, receives a roughing treatment on Deister sand tables, making a low-grade concentrate, which is re-cleaned, and discharging a low-grade tailing which goes to a large drag classifier. The overflow from the classifier is pumped to a system of fourteen 8-ft. Callow cones, having $\frac{3}{8}$ -inch discharge spigots. The spigot discharge is further treated by being passed over three Deister slime tables. The low-grade concentrate from these tables is re-cleaned, and the tailing is sent to the flotation sump.

The discharge from the Drag classifier goes to a 5 ft. by 22 ft. tube-mill, loaded with ten tons of 4-inch metallic (white iron) pebbles. The oil mixture is added to the tube-mill and is ground with the ore, the oil consumption being less than one pound per ton of ore treated. The tube-mill discharge passes a Dorr simplex classifier, the overflow of which goes to the flotation sump. The sand discharge from the classifier is carried by a spiral conveyer to a second tube-mill, 5 ft. by 22 ft., loaded with ten tons of $1\frac{1}{2}$ -inch white iron pebbles. A further addition of the oil mixture is made in this mill. The pulp, now ground to pass to 60-mesh screen, receives a further treatment on four No. 3 Deister slime tables, the concentrate from which is finished on a re-cleaning table. The tailing is discharged to the flotation sump.

The Primary Rougher Circuit.—The pulp is lifted from the flotation sump by a 6-inch centrifugal pump, to a distributor head-box in the flotation plant, and passes, at a dilution of 4:1, into three treble-length, double-compartment Callow rougher cells. Each primary rougher cell, with its series of three single length cleaner cells, is a separate circuit and is supplied with air at from four to six pounds pressure by a Connersville blower, operated by a 50-H.P. motor. The tailing from the rougher cells receives a final concentration treatment before being sent to waste. In each system of cells, the concentrate from the rougher cells passes to a double compartment cleaner cell which discharges its concentrate to a tank. A diaphragm pump lifts it to a second cleaner cell which discharges its concentrate to a second tank. It is lifted to a third cleaner cell for final treatment, the cleaned concentrate from which now assays 600 ounces of silver to the ton. This is discharged to a 20 ft. by 10 ft. Dorr thickener, dewatered on an Oliver continuous filter, and dried for shipment. Sodium silicate, in the proportion of fifteen pounds per ton of final concentrate produced, is added to the cleaner cells as a deflocculant.

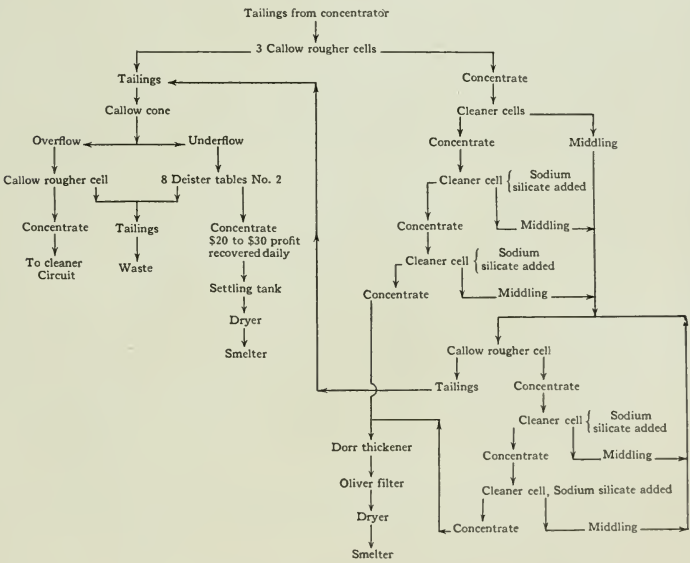
The Middling Circuit.—The tailings from the cleaner cells are known as the "middlings." The middling circuit is another separate unit. The system includes a double length (16 inch) double-compartment rougher cell, known as the middling cell, followed by two single length cleaner cells. The middlings flow to a sump, from which they are lifted by a 3-inch pump to the middlings rougher cell. The tailing from this cell joins the tailing from the three rougher cells for a final treatment by concentration. The concentrates from the middlings cell pass to the first cleaner cell. Sodium silicate is added to the concentrate from this cell, which is raised by an air-lift to the second cleaner cell,

where it receives the final treatment. The tailing from the two cleaner cells is returned to the middling circuit. The cleaned concentrate flows to the Dorr thickener.

The Tailing Circuit.—The tailing from the four rougher cells goes to a box and is lifted by a 4-inch centrifugal pump to an 8-ft. Callow cone. The underflow passes over eight No. 2 Deister sand tables, the concentrates from which are cleaned on a finishing table. The tailing from these tables goes to waste. The overflow from the Callow cone goes to a treble-length double-compartment rougher cell, the tailing going to waste. The concentrate is cleaned in a 9-ft. double-compartment cleaner cell, the tailing from which is returned to the middling circuit. The concentrate is sent to the Dorr thickener.

The Coniagas practice, as described above, is shown in outline in the following flow-sheet:—

TABLE XXXVIII



Flotation flow-sheet of Coniagas practice.

The following chart, taken at random, for the month of April, 1923, shows the results obtained at this plant.

TABLE XXXIX.—MONTHLY CHART OF THE CONIAGAS FLOTATION PLANT, SHOWING MONTHLY AVERAGES, TOGETHER WITH SIZING ANALYSIS AND ASSAYS OF THE DAILY TAILING, FOR THE MONTH OF APRIL, 1923

Monthly average.... {Flotation lead..... 3.40 ounces
 {Primary rougher tailing..... .79 "
 {Final tailing..... 1.23 "

Date	Percentage of weight				Assay: ounces of silver per ton			
	80	100	150	150	80	100	150	150
1st.....	9.89	9.44	16.40	64.27	2.0	1.6	1.4	1.7
2nd.....	11.75	7.44	14.14	66.67	1.6	.8	.7	1.4
3rd.....	15.34	7.62	16.19	60.95	2.0	1.2	1.0	1.8
4th.....	12.29	9.31	15.62	62.78	2.2	2.0	1.8	3.4
5th.....	9.82	10.48	14.81	64.89	1.8	1.6	2.6	1.8
6th.....	7.45	6.69	12.92	72.94	2.6	1.5	1.1	2.0
7th.....	10.63	9.19	17.12	63.06	1.0	1.7	.8	1.8
8th.....	6.13	6.28	17.52	70.07	1.6	1.0	1.0	1.4
9th.....	4.50	6.74	15.73	73.03	1.4	1.2	1.3	2.0
10th.....	12.12	10.05	14.83	63.00	.8	.8	.6	1.0
11th.....	9.22	8.68	15.55	66.55	1.0	.6	.5	.9
12th.....	9.56	8.53	15.56	66.45	1.1	.7	.4	1.0
13th.....	9.47	8.63	17.26	64.62	.7	.6	.4	.9
14th.....	12.37	8.44	14.56	64.63	1.0	1.1	.7	1.8
15th.....	5.89	7.68	18.03	68.40	.9	.6	.5	1.2
16th.....	7.06	7.55	14.22	71.17	1.0	.7	.6	1.2
17th.....	10.50	8.78	14.89	65.83	1.2	1.1	1.1	2.5
18th.....	8.52	7.40	14.01	70.07	.9	.7	.6	1.2
19th.....	9.02	9.13	14.60	67.27	.5	.8	.5	1.0
20th.....	9.34	7.00	16.93	66.73	.8	.6	.4	1.0
21st.....	9.19	6.85	14.64	69.32	1.0	1.1	.7	1.4
22nd.....	11.51	10.75	15.80	61.94	.6	.6	.4	1.2
23rd.....	10.89	8.35	13.61	67.15	1.7	1.1	.6	1.7
24th.....	6.02	7.98	17.26	68.74	.9	.6	.5	1.1
25th.....	6.06	7.19	15.99	70.86	1.3	.6	.5	1.0
26th.....	8.05	7.26	17.94	66.75	.8	.6	.7	1.2
27th.....	7.57	8.38	16.16	67.89	.9	.6	.5	1.1
28th.....	11.70	7.02	14.82	66.46	.8	.9	.6	1.5
29th.....	9.38	11.69	15.23	63.70	1.1	.9	2.3	1.7
30th.....	9.88	7.49	14.65	67.98	1.0	.8	.8	1.6
Average..	9.37	8.26	15.57	66.80	1.21	.96	.85	1.48

NOTE:—The difference between the rougher tailing and the final tailing is due to middlings.

TABLE XXXIXa.—ANALYSIS OF FLOTATION CONCENTRATES, CONIAGAS MILL, FEB. 27, 1923
 (Ag. 504.0 oz. ton, 1.7 per cent.)

	Per cent.
Insoluble	42.32
Pb.....	.21
Cu.....	3.55
Sb.....	1.32
As.....	5.98
Fe.....	14.80
Al ₂ O ₃	8.82
Ni.....	.55
Co.....	2.04
Zn.....	.12
CaO.....	5.23
MgO.....	2.25
S.....	8.35
Total.....	95.54

Additional Notes

Flotation of Cyanide Tailings.—The flotation process has not been combined successfully with cyanidation treatment, as each interferes seriously with the other. This fact was brought out by the attempt of the Nipissing mines in 1916-1917, to treat the tailing from the low-grade mill by flotation.

Owing to the increased cost of aluminium, which advanced in 1915 from 19 cents to over \$1.00 a pound, it was necessary to find a substitute for the desulphurizing treatment, in order to treat ores containing silver chemically combined with arsenic, antimony, and sulphur. On such ores, with a 48-hour treatment, straight cyanidation gave a poor extraction. The treatment of the cyanide tailing by flotation naturally suggested itself. Experiments to that end were conducted on a commercial scale for a period of over a year, but after trying many variations in the method of applying the treatment, the attempt was abandoned, as the results were not satisfactory. The low extraction of the precious metal was apparently due to the fact that the solvent action of the cyanide solution had pitted the surface of the base-metal particle containing the silver, so that it floated with difficulty. The flotation cells were discarded and the present practice was adopted, of gravity concentration on tables, followed by cyanidation. As already indicated, this practice has been found entirely satisfactory. Another factor in favour of gravity concentration in this plant was that it readily recovered the cobalt minerals in the ore. By the flotation treatment this valuable by-product for the most part was not recovered, as the arsenides are floated with difficulty.

The analyses of the flotation products from the Nipissing plant are shown in the following table—

TABLE XL.—ANALYSIS OF NIPISSING FLOTATION PRODUCTS

Schedule	Heads	Tails	Concentrates
Silver, ounces.....	7.12	2.4	729.9
	Per cent.	Per cent	Per cent.
Silver.....	0.025	0.008	2.50
Copper.....	Trace	Trace	2.70
Cobalt.....	0.17	0.16	0.21
Nickel.....	0.11	0.10	0.14
Arsenic.....	0.70	0.66	0.85
Sulphur.....	0.32	0.10	3.69
Insoluble.....	71.52	71.31	54.28
Iron and Aluminium.....	16.72	16.76	20.93
Lime.....	3.56	3.64	3.04
Magnesia.....	1.10	1.00	0.98
Volatile, H ₂ O, CO ₂ , etc.....	5.20	5.20	8.30
	99.425	98.938	97.62

The copper was paid for on the basis of five cents per pound.

Local Treatment of Concentrates.—A most serious objection to the flotation process is the difficulty of treating the concentrates to recover the silver as a fine bullion. Owing to the excessive marketing charges, the metallurgists of the district, and elsewhere, have experimented with practically every well-known process, in addition to carrying on a considerable amount of original research, in the effort to devise a satisfactory method of treatment. Fine grinding with straight cyanidation, and wet desulphurization followed by cyani-

dation have both failed. The principal difficulty is the excessive cyanide consumption (over 75 lbs. per ton of concentrates) which is due to the presence of large amounts of iron and copper mineral, as well as other base-metals, that act as cyanicides.

It was thought by some metallurgists that a chloridizing roast in the Holt-Dern furnace, followed by an acid-salt leach, might solve the problem. To try out this process, experiments were carried on at the Buffalo mines and the Dominion Reduction Company, the former installing a large furnace of this type and the latter four small ones. In both cases, after operating for several months, the process was abandoned, as it was not a success either commercially or metallurgically. On account of the fineness of the product, it was found impossible to get any large tonnage through the furnace. Furthermore, the product did not leach well, so that the extraction did not exceed 92 per cent. A still further disadvantage was the fact that the bullion recovered always contained a considerable amount of copper, which necessitated paying a refining charge.

All the flotation concentrates from the camp are shipped to smelters in the United States. Payment is made for the copper as well as the silver content.

The Cost of Marketing Concentrates.—The cost of marketing concentrates from the flotation process is shown in the following schedule. This brings out very clearly the marked advantage of shipping a high-grade rather than a low-grade product.

TABLE XLI.—COMPARATIVE RETURNS FROM DIFFERENT GRADES OF FLOTATION CONCENTRATES.

GENERAL:—

Freight Cobalt to smelter, per ton.....	\$24.40
Smelter treatment charge, per ton.....	14.00
Smelter refining charge, per ounce.....	.0014
Smelter percentage.....	5%
Representation and assaying, per ton.....	\$0.86
Estimated price of silver, per ounce.....	.65

100 OUNCE CONCENTRATE:—

Freight.....	\$24.40	Value.....	\$65.00
Treatment.....	14.00	Less.....	42.76
Refining.....	.25		
Percentage.....	3.25	Net.....	\$22.24
Representation and assaying.....	.86		
	<u>\$42.76</u>		

Percentage of total value of ore received..... 34.21

200 OUNCE CONCENTRATE:—

Freight.....	\$24.40	Value.....	\$130.00
Treatment.....	14.00	Less.....	46.26
Refining.....	.50		
Percentage.....	6.50	Net.....	\$83.74
Representation and assaying.....	.86		
	<u>\$46.26</u>		

Percentage of total value of ore received..... 64.41

300 OUNCE CONCENTRATE:—

Freight.....	\$24.40	Value.....	\$195.00
Treatment.....	14.00	Less.....	49.76
Refining.....	.75		
Percentage.....	9.75	Net.....	\$145.24
Representation and assaying.....	.86		
	<u>\$49.76</u>		

Percentage of total value of ore received..... 74.48

400 OUNCE CONCENTRATE:—

Freight.....	\$24.40	Value.....	\$260.00
Treatment.....	14.00	Less.....	53.26
Refining.....	1.00		
Percentage.....	13.00	Net.....	\$206.74
Representation and assaying.....	.86		

\$53.26

Percentage of total value of ore received..... 79.51

500 OUNCE CONCENTRATE:—

Freight.....	\$24.40	Value.....	\$325.00
Treatment.....	14.00	Less.....	56.76
Refining.....	1.25		
Percentage.....	16.25	Net.....	\$268.24
Representation and assaying.....	.86		

\$56.76

Percentage of total value of ore received..... 82.53

600 OUNCE CONCENTRATE:—

Freight.....	\$24.40	Value.....	\$390.00
Treatment.....	14.00	Less.....	60.26
Refining.....	1.50		
Percentage.....	19.50	Net.....	\$329.74
Representation and assaying.....	.86		

\$60.26

Percentage of total value of ore received..... 84.55

TREATMENT OF HIGH-GRADE ORE

Introduction

In the early days of the Cobalt camp the high-grade ore, together with the concentrates from the jigs and tables, was shipped to smelters in the United States for treatment. Later, special plants for treating these ores were built at Deloro, Thorold, Copper Cliff, and elsewhere. Owing to the complex nature of the ore, and the high arsenic content, this material was difficult to treat, and undesirable for the ordinary customs smelter. The general practice was to smelt in blast furnaces, recovering most of the silver as a base bullion. The resulting speiss was roasted and treated by wet methods for the recovery of the remainder of the silver, together with the cobalt and nickel. The arsenic trioxide from the roasting was recovered in bag-houses. The process was slow and required a large working capital as well as a heavy expenditure for plant.

In view of marketing difficulties, the management of the Nipissing, as early as 1908, undertook to investigate the possibility of treating the ore locally. A test plant was built, and a series of experiments carried out, with a view to developing a process by which the ore could be treated at the mine. It was desired that the process be at once efficient, inexpensive, simple to operate, one that did not require an expensive plant and that would produce the silver in a form ready to market as fine bullion. These experiments were finally successful and resulted in the building of the Nipissing high-grade mill, which began to operate in February, 1911.

Amalgamation and Cyanidation

The Nipissing High-Grade Mill

The process used at the high-grade mill, as developed by Chas. Butters and G. H. Clevenger, consisted of tube-mill amalgamation followed by cyanidation. In this plant only hand-sorted ore and jig concentrates were treated, as table concentration was not used at the Nipissing during this period. The process is fully described by R. B. Watson ("The Nipissing High-grade Mill," *Engineering and Mining Journal*, Dec. 7th, 1912). A brief outline of the process, based on Watson's article, is as follows:—

Sampling.—The high-grade ore was put through a 9 by 15 Blake crusher and fed to a No. 3 6-ft. Krupp ball-mill, carrying 1,000 lbs. of steel balls, and fitted with 20-mesh screens. The metallics were removed periodically from the ball-mill, and melted down in the refinery. The pulp from the ball-mill was delivered to a Vezin sampler and elevated to steel storage tanks.

Amalgamation.—The main operation consisted of amalgamating the silver in a tube-mill, by grinding the ore with mercury in 5 per cent. cyanide solution. For this purpose a Krupp mill was used, fitted with Silex liners and turning at 37 r.p.m. About one pound of mercury was used for every ounce of silver present, the ordinary charge being 6,500 lbs. of 2,500-ounce ore, 8,500 lbs. of mercury, 3,800 lbs. of 5 per cent. KCN solution, and six tons of pebbles. The mill was revolved for nine and a half hours, when 99 per cent. of the pulp would pass a 200-mesh screen, and the amalgamation was complete. By means of a special arrangement, compressed air was blown through the tube-mill to keep down the temperature, and to enable the cyanide to dissolve a greater proportion of the silver.

The charge was then dumped into an 8-ft. all-iron settler, fitted with wooden shoes. The amalgam was finally drawn off into canvas bags where it was allowed to drain, after which it still carried 78 per cent. of mercury. The pulp was discharged to the agitation tank for further treatment. The remarkable part about the whole process is that 97 to 98 per cent. of the total silver in the ore yielded to amalgamation in the tube-mill. Ore assaying 2,500 ounces to the ton was reduced to from 50 to 75 ounces when it left the settler.

Cyanidation.—The subsequent cyanidation of the pulp was relatively unimportant, as it dealt with the daily treatment of only six or seven tons of 50-ounce ore. A charge for agitation was made up of four tube-mill charges, or thirteen tons of dry pulp. Five pounds of lime were added per ton of pulp, and the charge agitated for thirty-six hours in 0.75 KCN solution in mechanically agitated tanks. After settling and decanting, the pulp was filtered on a Butters filter, and the clarified solution precipitated by passing through zinc-boxes filled with coarse zinc shavings. The residue left on the filter was stored. It contained thirty-five ounces of silver and fifteen to twenty pounds of mercury to the ton. This material has since become valuable for its cobalt content. An analysis of the residue is as follows:—

TABLE XLIII.—ANALYSIS OF RESIDUE FROM AMALGAMATION—CYANIDATION OF HIGH-GRADE ORE

Silver.....	35	Oz. Ton.	Arsenic.....	29.50	per cent
Nickel.....	9.72	per cent.	Sulphur.....	1.59	"
Cobalt.....	5.85	"	Silica.....	11.44	"
Iron.....	2.58	"	Lime.....	8.63	"
Antimony.....	3.80	"	Magnesia.....	2.91	"
Bismuth.....	0.09	"	Mercury.....	1.00	"
Copper.....	0.06	"	Alkali.....	}.....	Trace
Carbonic acid.....	13.55	"	Gold.....		
Combined water.....	5.74	"	Oxygen.....	}.....	3.15 per cent.
			Sn., Zn., Mn.....		

Determinations of the mercury consumption brought out the interesting fact, until then unsuspected, that the high-grade ore itself contained mercury, to the amount of two to five pounds per ton of ore. This was found to be contained in the metallics.

Retorting.—After draining in the sacks the amalgam was sent to the refinery, where it was weighed and charged into six 14 by 60-in. oil-fired retorts, arranged in batteries of two. The retorts were charged three-quarters full. They were fired for nine hours, and, after being allowed to cool for six hours, were then opened, and the resulting sponge weighed. The sponge assayed approximately 80 per cent. silver, the main impurities being arsenic, cobalt, nickel, antimony, and bismuth.

Refining.—The sponge from the retorts, in charges containing 28,000 ounces of silver, was melted down in an oil-fired reverberatory furnace. At first the furnace was lined with ordinary acid fire-brick, but later, magnesite brick was substituted to advantage. Air at fifteen pounds pressure was blown on the surface of the molten charge, from two iron pipes at the back of the furnaces. The oxides of cobalt, nickel, and other impurities rose rapidly to the surface, and were raked off through the charging door. No flux of any kind was required. The blowing was continued until the bullion was 999 fine, as determined by dip samples. It was then tapped into moulds.

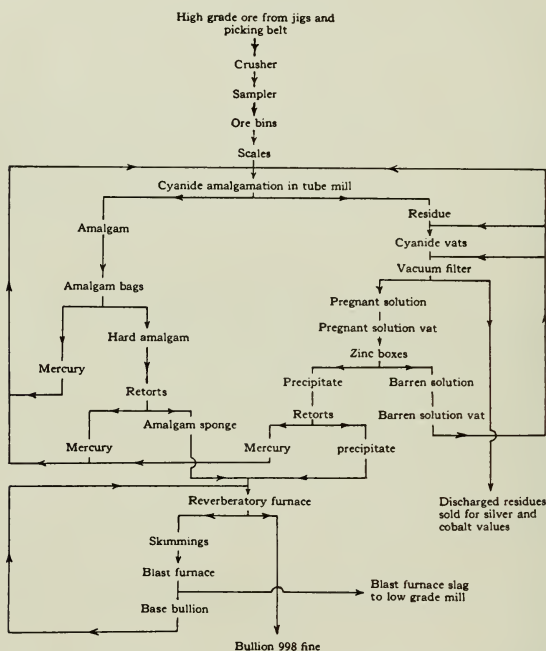
The waste gases were passed through dust chambers, to recover the mercury in the fumes. These consisted of brick chambers and two iron pipes 3 ft. by 27 ft., connected by brick work. The pipes were sprayed externally and at intervals sprays were introduced into the first pipe and the last chamber. Practically the whole recovery, amounting to 1,000 lbs. to 2,000 lbs. of mercury per month, was in the pipes, mostly in the first one, which was provided with the internal sprays.

Smelting.—A 20-in. round, water-jacketed blast furnace was installed to smelt the skimmings from the melting furnace, together with the flue dust, and the zinc precipitate from the cyanide plant. The flue from the furnace was connected with the dust chambers. Before being charged to the blast furnace, the flue dust and precipitate were retorted, then mixed with sugar-water, briquetted, and dried.

The skimmings assayed about 15,000 ounces, the flue dust 700 ounces, and the precipitate 15,000 to 18,000 ounces of silver to the ton. The charge was so rich in silver that no lead was necessary. The products were a base bullion, about 800 fine, which was melted down in the reverberatory furnace, and a slag carrying from five to eleven ounces of silver to the ton. A small amount of speiss was also formed. It was necessary to run the blast furnace only one day in ten, to clean up all the by-products.

Recovery and Costs.—The treatment, as outlined above, was remarkably efficient and expeditious, the silver being delivered as fine bullion, at New York, within a week of the day that the ore was delivered to the mill. Based on uncorrected fire assays, the recovery was as high as 99.5 to 100 per cent. Of this total. 95 to 96 per cent. was recovered by amalgamation, and 5 to 4 per cent. by cyanidation. The total cost of the plant was \$67,757.00, which includes the sampler, mill, and refinery.

TABLE XLIII



Flow-sheet of Nipissing high-grade mill. Tube mill amalgamation, 1911-1918.

Additional Notes on Amalgamation

Retorting.—The retorts were required to withstand hard and continuous service, and for this purpose retorts of cast iron proved to be unsatisfactory. Various grades of iron were tried, but all were found liable to crack, owing to the high temperature and the weight of the sponge. A soft grey iron, low in phosphorus, was found to give the best results. The average life of a retort was thirty-four charges, though occasionally a retort would break on the first firing. Later, retorts of cast steel and wrought iron were tried with better results.

A system of retorting using graphite crucibles was finally installed, and proved to be very satisfactory. A desirable feature of this system was that in one operation it permitted the retorting of the mercury and the melting down of the resulting silver sponge. It had the additional advantage of being cheaper and simpler to operate, and of requiring less fuel oil. A crucible was good for thirty-five melts.

In operation, about 1,200 lbs. of amalgam were charged into a No. 400 Morgan graphite crucible. After fastening down the cover, which was connected to the condensing pipe, the crucible was fired for a period of five hours, the heat being gradually increased up to the melting-point of silver. The tops

were then removed and the silver cast into bars of base bullion. Using this system of retorting, the mercury content of the base bullion was reduced to less than one per cent.

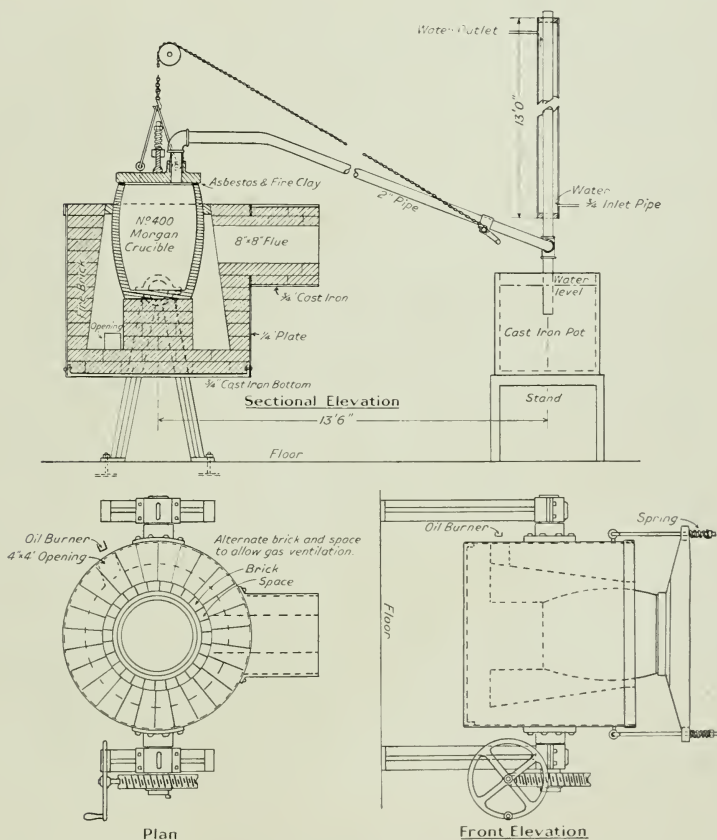


Fig. 67—Tilting retort, Nipissing Mining Company.

Mercury Content of Silver Sponge and Base Bullion.—On retorting the amalgam in iron retorts, the silver was left as a sponge bar 4 ft. by 10 in. by 6 in., which weighed about 900 lbs. The crucible system yielded a bar of base bullion. "Saw-cut" samples of these, made by sawing clean through the bar at the centre, and at both ends, were then assayed for mercury. It was found that the

mercury content of the solid portion of the sponge bar was always less than that of the porous portion; that usually it was lower at the centre than at the ends; and that it was less in the bar of base bullion than in the sponge bar. These facts are brought out in the following tables which show the analyses of a number of bars of both types.

TABLE XLIV.—DISTRIBUTION OF MERCURY IN SPONGE AND BASE BULLION BARS

Mercury content in sponge bar after retorting in iron retorts			Mercury content of bar of base bullion, after retorting and melting in crucibles and pouring into moulds		
BAR "A"—					
Solid end.....	1.75	per cent. Hg.			
Solid centre.....	1.62	"			
Porous end.....	3.14	"			
BAR "B"—			BAR "E"—		
Porous end.....	11.45	"	End.....	0.94	per cent. Hg.
Solid centre.....	1.91	"	Centre.....	0.86	"
Solid end.....	1.69	"	End.....	1.11	"
BAR "C"—			BAR "F"—		
This was half solid and half porous.			End.....	1.07	"
End.....	2.46	"	Centre.....	0.94	"
Centre.....	2.58	"	End.....	0.98	"
End.....	1.13	"	BAR "G"—		
BAR "D"—			End.....	1.24	"
This was porous throughout			Centre.....	1.01	"
End.....	3.28	"	End.....	1.02	"
Centre.....	2.29	"			
End.....	2.58	"			

Mercury Losses in the Residues.—The mercury lost in the residues was in the form either of floured mercury or of the sulphide HgS . As already noted, this amounted to fifteen to twenty pounds per ton. At the Nipissing high-grade mill, various attempts made to recover the lost mercury were not successful. For the most part the mercury was present in the residue in a finely divided metallic state, with only a small amount of the sulphide. This was due to the fact that, at the Nipissing mill, only clean high-grade ore and jig concentrates were treated, and this material was low in sulphur. This is shown in the following table:—

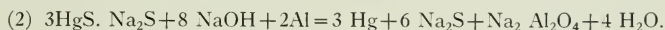
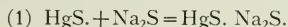
TABLE XLV.—SULPHUR CONTENT OF CLEAN HIGH-GRADE ORE FROM VARIOUS MINES, SAMPLED IN LOTS OF APPROXIMATELY 30 TONS.

Nipissing—average of 9 lots.....	2.98	per cent.
La Rose " 6 "	1.72	"
Kerr Lake. " 5 "	1.16	"
Cobalt Comet " 3 "	1.53	"
Crown Reserve " 2 "	1.16	"

Table concentrates, on the other hand, contain from 4 per cent. to 7 per cent. of sulphur, and the treatment of this material causes an excessive loss of mercury in the residue, most of it being in the form of the sulphide. This

was the cause of the high mercury losses at the Buffalo high-grade mill which was built in 1912 to treat the jig and table concentrates. The practice used was essentially the same as developed at the Nipissing, except that, in places, the same object was accomplished by the use of a different type of machine.

The Thornhill Process.—A process to recover the mercury from the current and accumulated residues was developed in 1914 at the Buffalo plant, and is described by E. B. Thornhill, metallurgist for the company¹. The process, successfully introduced by Mr. Thornhill, consisted essentially of leaching the mercuric sulphide from the residues by means of a caustic alkaline solution of sodium sulphide, and precipitating the mercury with metallic aluminium. The reactions involved are shown in the following equations:—



Since the dissolution of the mercuric sulphide is very rapid, no agitation was required, the solvent being applied to the residue on the filter leaf.

In practice, the pulp was caked on a Moore filter, and washed with water until free of silver solution. Sodium sulphide solution was then drawn through the cake, until the effluent solution showed only a trace of mercury. The strength of the solvent was kept up to 4 per cent. Na_2S and 1 per cent. NaOH . Usually one ton of solution per ton of residue was sufficient. The mercury was precipitated by agitating the mercuric sulphide solution with granular aluminium. After settling and decanting, the mercury was run off and strained through canvas.

The cost of treatment for labour and chemicals is given as thirteen cents per pound of mercury recovered. An interesting point is that the mercury recovered is very pure, and is absolutely free of arsenic.

The Buffalo practice, together with the sodium sulphide treatment of the residues, is shown in outline in the following flow-sheet of the Buffalo high-grade mill.

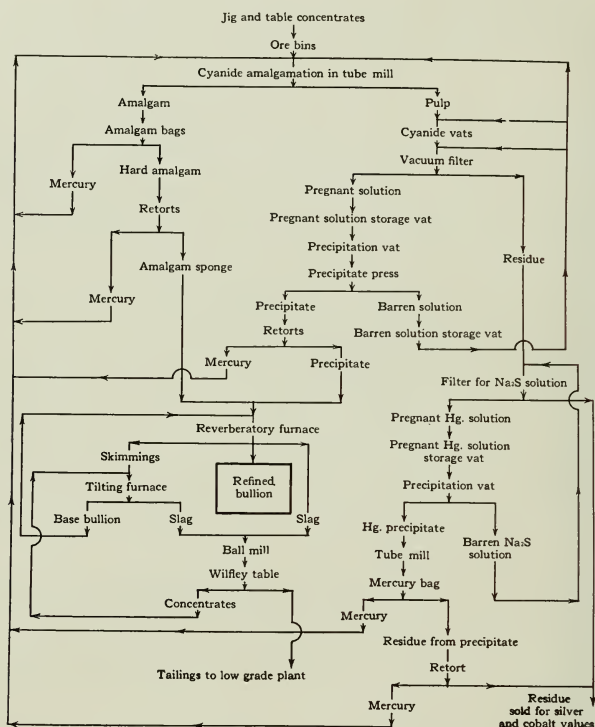
Losses of Mercury in the Stack.—A considerable amount of research work has been done at the Nipissing high-grade mill, to improve the recovery of values contained in the waste gases from the refining and smelting furnaces.

The original installation of brick chambers and water-sprayed iron pipes, to recover the dust and fumes from the waste gases, has already been described. Later improvements included the substitution of the crucible system of retorting, in place of the cast-iron retorts, which reduced the mercury content of the amalgam sponge to less than 1 per cent., and the addition of a bag-house to improve the recovery of fume.

The bag-house was 18 ft. 8 in. by 18 ft. 8 in. by 22 ft. 9 in., and contained forty-two woollen bags, each 20 in. by 22 ft. The gases were drawn through the older arrangement of dust chambers and passed through the bags, where a further recovery of the fume was made. The bulk of the material collected in the bag-house consisted of arsenic, antimony, nickel, cobalt, and bismuth, together with mercury and silver. The amount was surprisingly small, considering the nature of the material treated, and the volatile constituents that it contained. After starting the new high-grade treatment, no precipitate was

¹"Recovery of Mercury from Residues of Amalgamated Cobalt Ores," A.I.M.E. Trans., Vol. LII., 1915, p. 165; C.M.I. Trans., Vol. XLVI, 1915, p. 94.

TABLE XLVI



Flow-sheet of high-grade and mercury extraction plant, Buffalo Mines, Ltd.

found in the bags after a run of several months, and the bag-house practice was then discontinued. A stack 105 feet high was built at the end of the last dust chamber, to supply the draft in place of the fan.

Tests on Cottrell Process.—In January, 1915, tests were made with the Cottrell system for the precipitation of fumes on a portion of the gases before entering the bag-house. The volume of the stack gases was calculated from readings from a standard Pitot tube, and an Ellison differential draft gauge. Care was taken in every test to maintain the average reading in the sampling tube the same as in the stack.

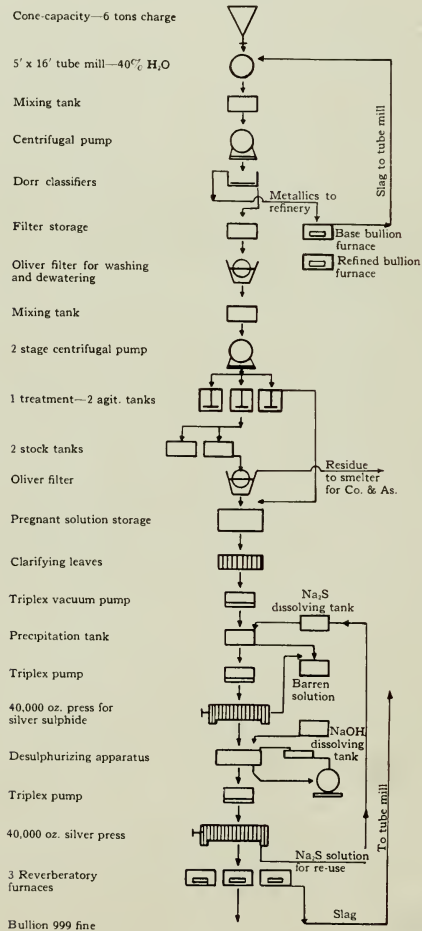
The results of these tests indicate that 90 per cent. of the dust carried by the total gases could be collected by the Cottrell system of fume precipitation. The Cottrell system was not installed, as the value of the increased amount of dust collected did not warrant the expense of changing over, particularly when the crucible system of retorting was developed at this period.

The results of some tests with the Cottrell system of fume precipitation are given in the following table:—

TABLE XLVII.—TEST ON PRECIPITATING DUST FROM REVERBERATORY FURNACES, BLAST FURNACE, AND RETORT GASES, BY THE COTTRELL SYSTEM OF PRECIPITATION OF FUMES

Test No.	Furnaces in operation	Furnace charge	Duration of test	Voltage on electrode	Electrode used	Temperature of gases	Velocity of gas per sec.	Total volume of gas through flue during test, cu. feet	Volume of gas treated cu. feet	Percentage of total gas treated	Weight of dust precipitated, lbs.	Dust that should be precipitated from total volume, lbs.	Assay of silver, ozs. per ton	Assay of mercury, lbs. per ton
1	H.C. reverberatory L.G. Blast furnace. Retorts.	1,500 lbs. base bullion, 1,150 lbs. amalgam sponge 20,000 oz. L.G. ppts. 15,000 oz. base-bullion 700 lbs. H.G. skinnings 1,222 lbs. mill clean-up 1,588 lbs. Nip. nuggets	10 hrs.	40,000	single No. 18 iron wire	24° C.	7.36	6,726,000	136,440	2.28	0.922	97.1	854.0	179.1
2	H.C. reverberatory Blast furnace.	1,500 lbs. base bullion 3,450 lbs. amalgam sponge Wood, rags and scrap Low-grade skinnings	48 hrs.	40,000	single 1/8-in. gas pipe	17° C.	6.58	31,624,000	570,240	1.80	0.797	22.2	222.0	416.9
3	H.C. reverberatory Blast furnace. Retorts.	2,000 lbs. amalgam sponge mill clean-up pan clean-up	24 hrs.	40,000 1/8-in. gas pipe and 6 No. 18 iron wires	7° C.	8.35	15,220,000	393,120	2.58	0.468	18.1	18.1	380.0	56.0
4	H.C. reverberatory Retorts.	2,400 lbs. amalgam sponge pan clean-up	17 hrs.	40,000 1/8-in. gas pipe and 6 No. 18 iron wires	17° C.	5.44	11,200,000	256,037	2.28	0.234	14.3	14.3	245.0	180.3
5	H.C. reverberatory Retorts.	2,100 lbs. H.G. ppts. pan clean-up	15 hrs.	40,000	single No. 18 iron wire	18° C.	3.71	9,882,000	109,000	1.10	0.266	39.0	403.0	138.6

TABLE XLVIIa



Cobalt Reduction Company, flow-sheet of high-grade plant treating 2000-3000 ounce ore.

Cyanidation

The amalgamation-cyanidation process, as described above, was used at the Nipissing mill for the treatment of high-grade ore and jig concentrates for a period of seven years, during which time it gave satisfactory results. The circumstances that led to the abandonment of amalgamation in 1918 were the result partly of economic disturbances caused by the war and partly of changes in the ore and in marketing conditions. The amalgamation process in operation required the use of large stocks of mercury as a working medium. During the war, the price of mercury advanced from \$33 to \$130 per flask of seventy-five pounds, and the inevitable losses of mercury in the residues and fumes, amounting to twenty-four pounds per ton of ore, became a serious matter. In addition to this, the character of the material to be treated had changed. As already outlined in the discussion of the treatment of low-grade ore, the low-grade mill, after experimenting with flotation, in 1918 adopted gravity concentration before cyaniding, and the high-grade mill was now required to treat the concentrates from the table and a less amount of high-grade ore. As the experience of the Buffalo mill had already shown, table concentrates are not amenable to the amalgamation process, owing to their high sulphur content and the presence of other impurities, which cause a heavy loss of mercury in the residues. For these reasons, the Nipissing management in 1918 decided to discontinue amalgamation, and adopted instead the hypochlorite cyanidation process which had already been developed, and was then in successful operation, at the Cobalt Reduction plant.

The problem of recovering the silver from high-grade ores and concentrates by cyanidation alone, without amalgamation, had long engaged the attention of the Cobalt metallurgists. As already pointed out in the discussion on the nature of the ore, the ordinary treatment of this material with cyanide gave disappointing results; the cyanide consumption was very high, and the extraction of silver was low. The high consumption of cyanide was due to the various cyanicides present, of which nickel was by far the worst offender. The low extraction was due to the presence of antimonial silver and various reducing compounds which interfered with dissolution. By continued research work, it was finally shown that a high extraction could be made with a normal cyanide consumption, if the ore was ground very fine to assist dissolution and given a preliminary treatment for the removal or oxidation of the base-metal compounds. The preliminary treatment oxidizes these compounds that would otherwise act as reducing agents, leaving the silver readily amenable to cyanidation. It has but little effect on the cobalt and nickel arsenides, which remain unaltered.

Two different preliminary treatments have been developed, the hypochlorite treatment and the acid wash. These will now be described briefly:—

The Hypochlorite Treatment

This process, developed in 1915 at the plant of the Cobalt Reduction Company, is still in operation. At the Nipissing it was substituted in 1918 for the older amalgamation-cyanidation process, and continued to be used until the development of the acid wash treatment in 1921. The practice used at the Cobalt Reduction and Nipissing mills is almost identical except for the present difference in the preliminary treatment.

Cobalt Reduction Company Practice

Sampling.—The wet concentrate from the low-grade treatment is mixed thoroughly and sampled by coning and quartering. Duplicate samples are taken and assayed for moisture and silver. A composite sample is made up every

month and assayed for cobalt and nickel. When the work is done carefully, this system of sampling is found to check with the silver recovered as bullion.

Grinding and Hypochlorite Treatment.—Five to seven tons of high-grade ore or table concentrates (4 mesh) are charged into a 5 ft. by 16 ft. tube-mill, loaded with 2-inch iron balls, and ground for eighteen hours with a dilution of 1:1. Calcium hypochlorite is then added at the rate of fifty to seventy-five pounds per ton of ore treated, depending upon the amount of sulphides present, and the grinding is continued for an additional six hours. The pulp is then discharged and fed to a Dorr classifier, to separate the coarse metallic silver from the slime pulp. The metallic silver discharged from the classifier is re-charged to the tube-mill with the next lot of ore, for further grinding. The slime overflow from the Dorr classifier, containing about 1 per cent. of plus 200-mesh sand, passes to a tank where it is settled and decanted to give a thickened pulp, having a dilution of 1:1. It is then discharged to an Oliver continuous filter, where the pulp is washed free of soluble chlorides.

Agitation.—Owing to the solubility of nickel arsenide in cyanide solution, and the effect which it has of re-precipitating the dissolved silver, it is imperative to get a rapid dissolution of the silver, and when once this is accomplished, to separate the pregnant solution from the ore as quickly as possible. This will result in the saving of considerable cyanide, and prevent the re-precipitation of the silver into the residues. Rapid dissolution of the silver is effected by treating the ore with a solution high in cyanide, at a high dilution, and by circulating the pulp with a 7-inch centrifugal pump, in order to aerate it thoroughly. In practice, washed cake from the filter discharges to a 20 ft. by 10 ft. mechanically agitated treatment-tank. The charge is made up to a dilution of 25:1, and the cyanide strength kept up to 0.5 per cent. The pulp is then thoroughly agitated and aerated for fourteen hours, after which it is allowed to settle for five hours and the excess solution decanted. The cyanide strength must not be allowed to fall below 0.2 per cent. KCN, as re-precipitation of the dissolved silver will then take place. The pulp is again agitated, and pumped to the stock tank for filtering.

Precipitation and Refining.—The precipitation of the silver with sodium sulphide and the subsequent desulphurizing and refining of the precipitate are identical with the Nipissing practice already described.

Recovery.—The treatment described gives a recovery of 97 per cent. of the silver contained in the high-grade ore and table concentrates, in a ninety-six-hour treatment.

Residues.—The residue discharged from the filter contains from fifty to seventy-five ounces of silver to the ton. The average analysis of this material, which is sold to the smelters for its silver and cobalt values, is as follows:—

TABLE XLVIII.—ANALYSIS OF RESIDUE FROM HYPOCHLORITE-CYANIDATION TREATMENT OF HIGH-GRADE ORE AND CONCENTRATES AT COBALT REDUCTION COMPANY

Arsenic.....	40.87 per cent.
Insoluble.....	8.24 "
Mercury.....	0.075 "
Copper.....	0.243 "
Sulphur.....	4.97 "
Lime.....	3.12 "
Iron.....	8.90 "
Cobalt.....	7.99 "
Nickel.....	7.68 "

The Acid-Wash Treatment

The preliminary acid-wash treatment replaced the hypochlorite treatment at the Nipissing high-grade mill in 1921. The Nipissing ores contain a greater amount of decomposed nickel compounds than do most ores in the district, and on this material the acid-wash treatment shows a greater saving in cyanide consumption than the older treatment with hypochlorite. The Nipissing practice is identical with that of the Cobalt Reduction in many respects. Only the more important differences are referred to here.

The sampling and grinding is identical with the Cobalt Reduction practice.

The ore is ground for twenty-three hours in charges of seven tons, in a 4 ft. by 25 ft. tube-mill under the conditions already described, and after settling and decantation in a tank, the 200-mesh pulp, with a dilution of 1:1, is pumped to a 20-foot by 10-foot wooden agitator tank, to receive the preliminary acid wash.

Acid Treatment.—The pulp is agitated for twelve hours with a 3 per cent. solution of sulphuric acid, the dilution being approximately 2:1. At the end of this period the acid strength is reduced to about 1 per cent., depending upon the amount of calcite in the ore. The dilution is raised to 12:1, and the pulp allowed to settle. The clear solution is then decanted and the washing operation repeated, to ensure the complete elimination of all soluble cyanides. The thickened pulp is then agitated at a dilution of less than 1:1, and lime is added to neutralize the acidity, before discharging to the cyanide tanks. No attempt is made to filter at this stage, as any surplus solution made in the high-grade circuit, from incomplete dewatering of the pulp, is transferred to the low-grade circuit.

Cyanide Treatment.—The pulp from the acid treatment is pumped to the cyanide vats, where it is agitated mechanically, and circulated at the same time with a 7-inch centrifugal pump for a period of eight to twelve hours. The dilution is about 35:1. Starting with 0.5 per cent., the cyanide strength is not allowed to fall below 0.25 per cent., in order to prevent re-precipitation of the silver. After filtering, the silver is precipitated with sodium sulphide, and the precipitate desulphurized and refined in the manner already described.

Recovery.—The treatment as outlined above gives a recovery of 98 per cent. of the silver in the ores and concentrates. The discharged residue carries from thirty to sixty ounces of silver to the ton.

Residue.—The residue from the treatment is stored and sold to the smelters. Payment is made for the silver and cobalt values. The composition of the residue is shown in the following table:—

TABLE XLIX.—ANALYSIS OF RESIDUE FROM ACID-WASH CYANIDATION TREATMENT AT NIPISSING HIGH-GRADE MILL

Cobalt (Co).....	7.31	per cent.
Nickel (Ni).....	10.35	"
Arsenic (As).....	33.79	"
Antimony (Sb).....	2.16	"
Silver (Ag).....	.24	"
Copper.....	Trace	"
Silica (SiO ₂).....	6.24	"
Alumina (Al ₂ O ₃).....	2.20	"
Iron (FeO—some Fe).....	9.64	"
Lime (CaO).....	10.26	"
Magnesia (MgO).....	1.22	"
Sulphur (S—mostly SO ₃).....	4.17	"
Carbon Dioxide (CO ₂).....	7.78	"
		95.54
Soluble in H ₂ O (alkali carbonate, sulphates, chlorides, etc.).....	6.42	"
Sulphate sol. in H ₂ O (SO ₃).....	.42	"

Treatment of Flotation Concentrates.—The various processes described above give excellent results when applied to the treatment of high-grade ore and jig and table concentrates. On flotation concentrates, on the other hand, the results are unsatisfactory. This is due to the fact that flotation concentrates are low-grade and carry large amounts of base-metal impurities that destroy cyanide. The film of oil surrounding the particles serves also to protect the silver from the dissolving action of the cyanide solution. The treatment of flotation concentrates has already been discussed (see under treatment of low-grade ore flotation), and will not be referred to further here.

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Ont. Dept. of Mines Report, Vol. XXVII, 1918, Part III, Cobalt, pp. 64-69.
- WRIGHT, SYDNEY B.
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- GROCH, FRANK.
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"Smelting and Refining of Cobalt Silver Ore,"
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- FAIRLIE, M. F.
"Extraction of Silver from Ores,"
Pitman's Common Commodities. By Benjamin White.

Descriptions of milling practice are also given in the annual reports of the operating companies; in the annual reports of the Ontario Department of Mines; in Mr. A. A. Cole's annual reports to the Temiskaming & Northern Ontario Railway Commission.

CHAPTER V

LITERATURE ON GEOLOGY¹

By Cyril W. Knight

INTRODUCTION

Before the discovery of Cobalt in 1903, detailed geological work had not been accomplished in the Cobalt silver area. This was due chiefly to the fact that no ore-bodies had been discovered which were of sufficient importance to encourage accurate geological surveys, and partly also to the fact that the region was remote from railways and was settled in but one or two isolated places, such as Haileybury, New Liskeard, and a few localities on the east side of Lake Timiskaming.

Accordingly the reports on the geology were general in character, and the geological maps faulty and published on a small scale.

There is little necessity in this review of the literature to summarize the early reports published prior to 1903, of which there are only a few. Sir William Logan wrote the first general account of the rocks when he examined the shores of Lake Timiskaming in 1845-46. The only other report of importance was written by Dr. Alfred E. Barlow many years after, in 1897. Barlow covered a very great area, 6,912 square miles, and published a geological map extending from Lake Nipissing on the south to the head of Lake Timiskaming on the north. In such a vast area, it was clearly impossible with the financial resources then available to do detailed geological work. But Barlow's topographic survey of the main waterways was extraordinarily accurate and will remain a monument to his careful and painstaking labour. Moreover, he mapped in a general way the outlines of the diabase and suggested that in certain localities it appeared to occur in the form of a sheet or sill. In later years Miller named this rock the Nipissing diabase and showed that it was the source of the silver ores.

Thus there are but two reports of importance in the period preceding the discovery of Cobalt, that by Sir Wm. Logan and that by Dr. Alfred E. Barlow.

Any one desirous of delving into the literature of that time will find an excellent review in Dr. Barlow's report and in Bulletin No. 360 of the United States Geological Survey.

It may be noted here, however, that the discovery of a body of silver-lead ore, the Wright silver mine, on the east shore of Lake Timiskaming, was made in the year 1686. A very interesting account of the finding of this deposit has been written by Mr. J. A. McRae. A reprint of Mr. McRae's article will be found in following pages.

Coming now to the second period, namely, that following the discovery of Cobalt, a higher standard begins to develop in the literature dealing with Cobalt and other great camps of northeastern Ontario. The reports cover smaller areas and the maps are on a larger scale and of increasing accuracy and exactness. In the twenty-one years which have elapsed since the discovery of Cobalt, the

¹The list of reports on milling and metallurgy is given in Chapter IV.

complex structure of the rocks has gradually been unravelled. Its complexity, indeed, is much greater than was imagined by the early geologists. If we compare, for example, Barlow's summing up in the year 1897, of the age relationships of the rocks with that of to-day, it will be seen that the advance in the science of geology has been rapid and great.

Barlow, for instance, divided the rocks into the following simple divisions:—

PALEOZOIC.....	Silurian, Cambro-Silurian.
ARCHEAN {	Huronian.....Diabase and gabbro, conglomerate, greywacké, quartzite.
	Laurentian (including Grenville series) granite, gneiss, crystalline limestone.

If this table be compared with the table showing the complex subdivisions given in the legend on page 30 of this report, a proper understanding of the advance in our knowledge of the geological history of the area will be realized. It should be noted, however, that Barlow's report did not cover the Matachewan area in which the Matachewan series was subsequently discovered by Burrows.¹

In the second period, that following the discovery of Cobalt, the outstanding report on the Cobalt silver field is that by Dr. Willet G. Miller, which was published in four editions.

In the following summaries, it is not practical to attempt to summarize fully the four editions of Miller's report; any one desirous of becoming familiar with the geology of the Cobalt area must consult Miller's work. As noted elsewhere copies of his report are still available. Certain parts of Chapter I of the present report give Miller's conclusions in regard to the general geology, ore deposits, and mineralogy. It is not necessary, therefore, to repeat these summaries in Chapter V.

In addition to the reports summarized below, there will be found much information on mining and the treatment of the ores in the annual reports of the Temiskaming and Northern Ontario Railway by Arthur A. Cole.

The annual reports of the mining companies also give much information, particularly regarding costs of mining and treatment of the ores.

A few of the papers which have been written on the Cobalt silver field are not mentioned or summarized in the following pages. Some of these are brief notes, or discussions, which would not add much to the value of this chapter.

The literature has grown to such proportions that the summaries are of necessity, for the most part, brief.

SUMMARIES OF LITERATURE

Miller,² in December, 1903, publishes the first report on Cobalt a few months after the deposits were discovered. In view of the importance of this paper it is reprinted below in full:—

During the last month, the discovery of deposits of cobalt-nickel-arsenic and silver ores in the northern part of the Province of Ontario has been made public. Little importance appears to have been attached to the deposits by those who first saw them, it being thought that they carried a small amount of copper, the niccolite being mistaken for this metal. The Director of the Bureau of Mines,³ however, when on a recent visit to the district, received specimens of the minerals, and recognized that they represented valuable ore. The writer was, accordingly, instructed to make as thorough an examination of the deposits and surrounding area as could be made at the season of the year, snow having already begun to fall in the district.

The deposits were discovered during the building of the Temiskaming & Northern Ontario, the government railway, which is now under construction from North Bay junction, on the Canadian

¹The Matachewan Series and its pre-Cambrian Relations, by Willet G. Miller; Can. Min. Jour., April 20, 1923.

²Cobalt-Arsenides and Silver in Ont., by Willet G. Miller; Eng. Min. Jour., Dec. 10, 1903; Can. Min. Rev., Vol. 22, No. 12, Dec. 31, 1903, pp. 245-249.

³Thos. W. Gibson.

Pacific, to the head of Lake Temiskaming. The road-bed of this new railway runs almost over the top of the first of the deposits discovered. The deposits lie five miles south of the village of Haileybury, one of the two sister villages on the Ontario side of the northern part of Lake Temiskaming. Haileybury, following the railway, lies about 106 miles north of North Bay station, which is, by the Grand Trunk Railway, 227 miles north of the city of Toronto.

As the deposits were discovered quite recently, and snow has fallen in that district, very little prospecting has been done in the surrounding area. The discoveries were made by men employed on the railway, and not by regular prospectors; hence the work has not been done as systematically as it might have been.

When I visited the locality, recently, four veins or deposits had been located in the vicinity of a small body of water known as Long lake, which is not shown on existing maps. It lies about one-half mile south of the southern boundary of lots 8 and 9 in the first concession of the township of Bucke. The reports of other finds were not verified.

Each of the four veins visited was found to carry cobalt. Nickel also appears to be present in all of them; but as the weathering of the cobalt compounds masks, at times, the nickel colours, this latter metal was not definitely recognized in two of the deposits, although it doubtless occurs wherever the cobalt is found. Three of the veins are rich in native silver. The veins occur in unsurveyed territory, and, as the locations are as yet unnamed, we shall speak of them as Nos. 1, 2, 3 and 4. The outcrop of No. 2 lies about one-half mile southwest of No. 1, and No. 3 the same distance southwest of No. 2. The outcrop of the fourth vein is about one-half mile southeastward of No. 3.

Very little work has been done on any of the veins, and as the surface is pretty well filled by moss and soil, it is impossible to state what is their horizontal extent.

All of the veins cut through one or both of the formations known in the district as Huronian slate and breccia-conglomerate. The latter rock is considered to be composed of volcanic ejectamenta—grains and fragments of rock of various kinds which have become consolidated. The slate conglomerate of older Canadian writers, Logan and Murray, is a variety. The slate along the railway cuts, in the vicinity of Long lake, contains occasional fragments of pink granite, which are, at times, a couple of inches or more in diameter. On the faces of some of the vertical cliffs, the well-banded slate at the bottom is found to pass gradually into massive breccia-conglomerate at the top, the fragments in the latter being of varied composition, and ranging in size from small grain-like fragments to pieces of rock a foot in diameter.

I have had no opportunity of making a laboratory study of the specimens of rocks collected. The presence of dikes or sheets of some of the darker-coloured eruptives was suspected, but they were not definitely recognized. In the field they would resemble rather closely some of the more massive varieties of the slate and finer-grained breccia.

The slate and conglomerate have a slight dip, and the veins referred to cut them almost vertically. The strike of veins Nos. 1 and 3 is approximately northeast and southwest; that of 4 is east and west; that of 2, northwest and southeast. Diabase and gabbro invade these fragmental rocks in some parts of the district, and appear to underlie most of the area. About three miles to the northward of Long lake, Silurian limestone overlies the Huronian, but the limestone is undoubtedly of younger age than the veins.

Vein No. 1 lies east of the railway track, at the edge of a swamp, about one-quarter mile north of the end of Long lake. It has been uncovered at three points, which are within a few yards of one another. As the surface of the rock is low here, and little of it is exposed, it is difficult to tell much about the form of the deposit. Medium grained, dark-coloured conglomerate is found on one wall. At the widest opening the deposit has a width of over 6 feet, but the vein matter is more or less mixed with rock. The ore consists of niccolite, or the arsenide of nickel, and smaltite, the diarsenide of cobalt, together with much native silver. Niccolite contains, theoretically, 43.9 per cent. of nickel and 56.1 of arsenic. Smaltite carries 28.2 per cent. of cobalt and 71.8 of arsenic. It may be added that the ore of nickel now worked in Ontario, the iron sulphide or pyrrhotite of Sudbury, in which nickel occurs not as an essential but as an accidental constituent, carries, on the average, less than 5 per cent. of the metal. On weathered surfaces the vein matter is coated with the beautiful pink decomposition product, cobalt bloom. The green nickel stain is also seen on some surfaces, but is usually masked by that of the cobalt. This nickel compound is probably the arsenate, annabergite, but nickel silicate may also be present. The secondary mineral, arsenolite, is present. The native silver occurs as films, or leaves and fine threads, or moss-like forms, through the nickel and cobalt minerals, especially in the niccolite, as well as in cracks in the rock and in the calcite veinstone. In weathered portions of the ore the silver shows distinctly. Some lumps of weathered ore, weighing from 10 to 50 lb., carry a high percentage of silver. One sheet, composed chiefly of silver, attached to a rock surface, had a thickness of nearly 0.375 inch and a diameter of about 1 foot. The silver appears to have crystallized earlier than the niccolite, which has been deposited around it. The cobalt arsenide has formed still later than the niccolite. As so little work has been done on this ore-body, it is difficult to determine whether the three openings belong to one vein, or whether the ore occurs in a more irregular deposit, although the chief opening appears to be on a vein-like body. The ore is undoubtedly very rich, containing values in nickel, cobalt, silver and arsenic, and a comparatively small vein could be worked at a handsome profit.

On location No. 2 the ore-body is distinctly vein-like in form. The ore here is a mixture of smaltite, and probably some closely related arsenides of cobalt, such as safflorite and niccolite. The only complete analysis which has yet been made of the ore from this locality was that of a sample from this vein. It was found to have the following percentage composition: Cobalt,

16.8; nickel, 7; iron, 6.3; arsenic, 69; rock matter, 0.9; total, 100. This ore-body, unlike the other three examined, carries no silver in the parts so far uncovered. Three openings have been made on the vein over a length of 300 feet. The massive ore has a width of 14 inches but vugs in the wall-rock, 2 feet or more from the vein, are filled with cobalt bloom. The rock of both walls is slate. The walls are well defined, and the vein dips almost vertically, the strike being toward the southeast. The vein lies on the hillside, a few hundred yards east of Long lake and the railway, and, unlike ore-body No. 1, is at a height of about 70 feet above the water level. Although the width of this vein is not great, the character of the ore is such as to make it promising, at the present prices of the metals contained in it.

The ore has a massive appearance, and a rather dark-gray colour, where not coated with cobalt bloom. When examined carefully, however, in hand specimens, especially if a polished surface be examined with a magnifying glass, it is seen to be a mixture of a gray mineral, which is chiefly smaltite, and the reddish mineral, niccolite. Smaltite and the corresponding arsenide of nickel, chloanthite, are claimed by most authors to pass into one another by the substitution of cobalt for nickel, and *vice versa*. Niccolite, in the analysis quoted by Dana and others, carries only a small percentage of cobalt and iron, while smaltite and the other diarsenides of cobalt frequently contain much iron and nickel. In the ore under consideration, the cobalt and nickel appear to be, for the most part, in distinct compounds. In the analysis quoted, if we consider the 7 per cent. of nickel to exist as niccolite, and the percentages of iron and cobalt, 6.3 and 16.8, respectively, to exist as smaltite, the theoretical percentage of arsenic in the ore should be 68.47, instead of 69, as found by analysis. The percentage of niccolite by weight would be 15.94, or about one-seventh part of the whole by volume, since niccolite has a somewhat higher specific gravity than smaltite. The specimens, when examined with the magnifying glass, agree with this. The niccolite has crystallized earlier than the smaltite, which forms the ground-mass through which the niccolite grains are set.

Minute, brilliant, silver-white or tin-white crystals occur sparingly, embedded in the wall-rock and in the ore. The crystals occur in cubes, and in combinations of this form with the pyritohedron, or rhombic dodecahedron, and octahedron. An analysis is required to determine whether they are smaltite, cobaltite, or some related compound. The smaltite shows a tendency to form globular or spheroidal masses, with a radiated structure. The ore is somewhat porous, spaces being left between the globules, which are tarnished almost black on their surfaces. Where not coated with cobalt bloom, the weathered surface of the ore has a dark colour, not unlike that of the wall-rock. On a fresh surface, the more massive ore resembles mispickel, but is somewhat darker in colour. Small grains of quartz are found sparingly in the ore. The proportion of nickel to cobalt in this case is less than that in No. 1. A more detailed study of the form and chemical composition of the minerals is being made.

Ore-body No. 3, so far as could be seen, is similar in character to No. 1. It lies at the southern edge of Long lake. The ore consists of native silver, smaltite and cobalt bloom, and, in all probability, niccolite also.

Vein No. 4, although having the smallest width of the four, is, in many respects, the most interesting of the group. Here a perpendicular bare cliff of rock, 60 or 70 feet high, faces west. The vein, whose width averages not more than 8 inches, cuts this face at right angles, and has an almost vertical dip. The vein is weathered away, leaving a crack in the face of the cliff 2 feet, in some places 4 or 5 feet, in depth. When I saw it first, it had not been disturbed. Thin leaves of silver up to 2 inches in diameter were lying on the ledges, and the decomposed vein matter was cemented together by the metal, like fungus in rotten wood. It was a vein such as one reads of in text books, but which is rarely seen, being so clearly defined and so rich in contents. It was found impossible to get a fresh sample of the ore with the prospecting-pick, the vein being so much decomposed. The weathered specimens, however, in addition to the native silver, contained cobalt bloom; and the unaltered ore will be found, in all probability, to consist of smaltite and niccolite, in addition to the silver. It may also be added that, in one part of the vein, a distinct banded structure was noticed. Across a distance of 8 inches there were 12 or 14 layers of ore lying parallel to the walls. At the bottom of the cliff the vein cuts thin, banded, dark-gray or greenish, at times almost black, slate, which has a slight dip. This slate passes gradually, so far as could be determined from the steep character of the cliff, into coarse breccia-conglomerate in the upper part. The fragments in the conglomerate consist of quartz-slate, granite and other rocks.

On some of the weathered surfaces of the native silver specimens there are small, black, spheroidal masses, with little lustre. These appear to be the hydrated oxide of cobalt, heterogenite. Some of the deposits on the silver resemble asbolite. The carbonates of cobalt and nickel are also probably present. Antimony and sulphur have been detected in the ore of veins 1 and 2. Detailed analyses are required to determine the character of some of the silver-bearing minerals, which are present in small amounts. Bismuth, copper and manganese, in an association of ores such as we have in these deposits, are to be looked for.

These recently-discovered ore-bodies lie about 90 miles northeast of the town of Sudbury, in the vicinity of which are situated the well-known nickel mines. The ore of the latter is of a different character from that of the Haileybury deposits, being essentially pyrrhotite and copper pyrite. The rock associated with the Sudbury deposits, which are not veins, but deposits of irregular shape, is norite, a variety of gabbro; the ore itself is claimed by most writers to be of igneous origin. It is thus seen that there is little in common between the ore-bodies of the two localities, with the exception that nickel is a characteristic metal of each. The Sudbury pyrrho-

tites carry a small percentage of cobalt in addition to nickel. The minerals niccolite, danaite, and other arsenical compounds, have been found in some of the Sudbury deposits, but only in small quantities.

It is of interest to note that a deposit of sulph-arsenide of iron, mispickel, was discovered a few years ago near Net lake, which lies about 25 miles to the southwestward of the Haileybury deposits. This mispickel, however, does not carry appreciable amounts of nickel, cobalt or silver.

On the Quebec side of Lake Temiskaming, about nine miles to the northeastward of the Haileybury deposits, a deposit, known as the Wright silver mine, was discovered many years ago by some of the early explorers of that region. During recent years, this deposit has been worked for its lead and silver contents. The deposit is unique in character, the wall-rock being Huronian breccia-conglomerate, the fragments in which are, at times, cemented together by argentiferous galena.

The only area in Ontario or central Canada which has hitherto been found to contain deposits of rich silver ore is that which lies near the head of Lake Superior. While native silver has been found in considerable quantity in these deposits, the sulphide, argentite, is the more characteristic ore. The Silver Islet mine, near Port Arthur, is well known to those interested in the metal industry. Deposits of somewhat similar character, which occur on the mainland, have also been frequently described. The report of Mr. E. D. Ingall, of the Canadian Geological Survey, published some years ago, gives a particularly full account of this silver-bearing area.

The silver veins in the vicinity of Port Arthur, like those of Haileybury, cut through slate, but the Port Arthur slates are held to be of later age—Animikie—than those of Haileybury, which are what is called, in a general way, Huronian. Much work remains to be done on our metamorphic and igneous rocks before the various formations can be correctly correlated. Both the Port Arthur and Haileybury slates have been disturbed by eruptions of diabase and related rocks.

Although cobalt and nickel minerals have not been found in quantity near Port Arthur, it is interesting to know that the ore of the Silver Islet and some of the other mines was, at times, found to be coated with cobalt bloom. Niccolite and other minerals carrying cobalt and nickel occur in small amounts in some of these deposits. The only deposit in which quicksilver has been found in Ontario is that of Silver Islet, where chloride of silver is also said to occur as a decomposition product.

Small quantities of cobalt, nickel and silver-bearing minerals occur on Michipicoten island, Lake Superior. Arsenical compounds of the first two metals have been found at several other localities in Ontario and at Calumet island, Quebec. It will be noticed that the association of minerals in these Haileybury veins is not unlike that found in some well-known deposits of Germany and other countries.

Although little prospecting has been done in the vicinity of the Haileybury deposits, it would appear, from the discoveries already made, that ore-bodies occur there which can be worked profitably for the metals which have been mentioned. It is scarcely probable that nickel will be found in sufficient quantity in these deposits to interfere materially with the lower grade, but large, deposits of the Sudbury area.

Slate and conglomerate, similar in character to those of Long lake, cover a very large, as yet little prospected, area in northern Ontario. These rocks, along the government railway, a considerable distance south of the deposits described in this paper, contain indications of the presence of cobalt ore.

It is stated in "The Mineral Industry" that "cobalt, which is used in the arts, chiefly in the form of oxide, is obtained from New Caledonia, Australia and Germany, and smelted in France, Germany and Great Britain, the Messrs. Vivian, of Swansea, being the chief buyers in the last-named country." Cobalt oxide is produced at one plant in the United States.

The ore of New Caledonia, which is the world's largest producer, shipping about 3,000 tons yearly, is cobaltiferous wad, containing 25 to 30 per cent. manganese and 2 to 8 per cent. cobalt oxide (CoO). The ore of New South Wales is similar in character. In both countries the cobalt ore is a decomposition product, and occurs in irregular deposits, similar to those of bog iron ore.

At the end of 1901 and the beginning of 1902 the price of cobalt ore, containing 4 per cent. cobalt, in New Caledonia, was forced up higher than circumstances warranted. For a long time the price in Europe did not justify more than 90 fr. per ton being paid for this quality of ore at the mines, but the price steadily rose to 330 fr. (about \$66) until recently, since which it has receded. The black oxide of cobalt sells at from \$2.26 to \$2.30 per pound, or the metallic cobalt in the compound brings about \$3 per pound. It would thus seem that the refiners should make a much larger profit than the miners. The market will not, however, stand a greatly increased production without the prices materially decreasing. It is claimed that there has been a combination among refiners to keep up the prices of the artificial cobalt products.

I would be pleased to receive inquiries from buyers of Cobalt ore, and other minerals which are associated with it in the vicinity of Haileybury, with the object of putting them into communication with producers. Shipments could be made during the coming winter.

Miller,¹ in 1904, gives a preliminary description of the rocks and of the four veins first discovered around Cobalt lake. This paper is substantially the same

¹The Cobalt Nickel-Arsenides and Silver Deposits of Timiskaming, by Willet G. Miller, Ont. Bur. Mines, Vol. XIII, pt. I, pp. 96-103.

as that published in the "Engineering and Mining Journal" on December 10th, 1903. Some further material is, however, added.

Barlow,¹ in 1904, finds that the iron formations at the northeast part of Lake Timagami belong to a much older series than what he had hitherto described as Huronian in this district. The iron formations with accompanying green schists, slates, dolomites, and schistose eruptives, and intruded by granites, belong to a series which had been intensely folded, metamorphosed, and considerably eroded before the deposition of the overlying conglomerate hitherto described as the basal member of the Huronian system in this region. The larger fragments in the conglomerate are principally pebbles of granite and greenstone derived from the degradation of this underlying series.

Barlow believes that the Vermilion iron range of Minnesota is very closely related, if not identical in character and age with the iron-bearing ranges outcropping in the vicinity of Lake Timagami. Both have highly inclined attitudes with very brilliant associated jaspers.

Parks,² in 1904, describes the veins and rocks in the area around Cobalt lake, and also the rocks north of Lake Timiskaming.

The age to be ascribed to the rocks around Cobalt and their position in the complex formations constituting the most ancient rocks of the earth, is a matter to be approached with some hesitation. When the greatest authorities differ it is very difficult to decide on the proper nomenclature.

Young,³ in 1904, finds that in the area between Rabbit and Timagami lakes the oldest series of rocks consists chiefly of schists, chloritic, sericitic, and hornblende. The schists are penetrated by masses of granite and syenite. The schists, granite, and syenite are unconformably overlain by conglomerate, slate, and quartzite. These sediments rest horizontally and are frequently capped by sills of diabase. The different areas of diabase throughout the district are, it is tolerably certain, all parts of a once continuous sill.

Miller,⁴ in 1905, publishes his first full report on Cobalt. This report was based on field work of 1904. He classifies the rocks according to the following table:—

NIAGARA.....Limestone with a small amount of sandstone and conglomerate at its base.

Great unconformity

PRE-CAMBRIAN

DIABASE AND GABBRO...Animikie or Keweenaw in age.

MIDDLE HURONIAN.....Lorrain arkose, quartzite, and conglomerate.

Unconformity

LOWER HURONIAN.....The Cobalt series, consisting of conglomerate, breccia, quartzites, and greywacké-slate.

Great unconformity

KEEWATIN.....An igneous complex, consisting of greenstones, quartz-porphyrines, and other rocks.

Igneous contact

LAURENTIAN.....Lorrain granite.

¹ The Timagami District, by Alfred E. Barlow, Sum. Rept., Geol. Surv. Can., 1903, pp. 120-132.

² The Geology of a District from Lake Timiskaming Northward, by Wm. A. Parks, Geol. Surv. Can., Vol. 16, 1904, pp. 198A-255A.

³ On Surveys between Rabbit and Timagami Lakes, by G. A. Young, Sum. Rept., Geol. Surv. Can., 1904, pp. 195-198.

⁴ The Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming, by Willet G. Miller, Ont. Bur. Mines, Vol. XIV, pt. II, 1905.

In the Lower Huronian (Cobalt series) conglomerate, he finds granite boulders of great size and he speculates as to the possibility of the conglomerate being glacial in origin. He thinks that in the present state of our knowledge there is little warrant for claiming that these granite boulders, often two or three feet or more in diameter and distant a couple of miles from exposures of the rock, indicate glacial conditions during Lower Huronian times, although there is no proof to the contrary.

He believes that the material in the silver veins has, in all likelihood, been deposited from highly heated and impure water which circulated through the cracks and fissures of the crust and were probably associated with the diabase eruption.

Bell,¹ in 1905, reports on the Cobalt mining district.

Hardman,² in 1905, describes a new mineral area in Ontario.

Campbell and Knight,³ in June, 1906, work out the paragenesis of the cobalt-nickel arsenides and silver deposits of the Cobalt area. Beginning with the earliest they believe the following to be the order in which the minerals were deposited: (1) smaltite-chloanthite, (2) niccolite, (3) calcite, (4) argentite, (5) native silver, (6) decomposition products (erythrite, annabergite, etc.). This order was worked out by examining polished surfaces of the ore by means of reflected light under the microscope.

Campbell and Knight,⁴ in September, 1906, make a microscopic examination of polished surfaces of the silver ores from Cobalt. Although all of the structures met with in this examination cannot be satisfactorily explained, they point to the following order of origin for the principal constituents: First came the smaltite, closely followed by the niccolite; other minerals in small amount came down at this time. Then, after a period of slight movement in which the first minerals were more or less fractured, calcite was deposited as a ground-mass. Later came argentite, which was followed by native silver and native bismuth. Lastly came the surface decomposition products, erythrite and annabergite.

Arranged in tabular order, the succession is then as follows:—

Smaltite.
Niccolite.
Period of movement and fracturing.
Calcite.
Argentite.
Native silver.
Native bismuth.
Period of decomposition.
Erythrite and annabergite.

Miller,⁵ in 1906, publishes the second edition of his report on Cobalt. This is substantially the same as the first edition.

Van Hise,⁶ in 1907, after having spent about a month during each of two seasons in the Cobalt area, is convinced that there have been two periods of concentration in the ore deposits. The first concentration occurred under deep-

¹ Cobalt Mining District, by Robt. Bell, Sum. Rept., Geol. Surv. Can., 1905, pp. 94-104.

² A New Mineral Area in Ontario, by J. E. Hardman, Can. Min. Rev., Vol. 24, No. 5, May, 1905, pp. 95-98.

³ The Paragenesis of the Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming, by W. C. Campbell and C. W. Knight, Eng. Min. Jour., June 9, 1906.

⁴ A Microscopic Examination of the Cobalt Nickel Arsenides and Silver Deposits of Timiskaming, by W. Campbell and Cyril W. Knight, Econ. Geol., Vol. 1, No. 8, Sept.-Oct., 1906.

⁵ The Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming, by Willet G. Miller, Ont. Bur. Mines, 1905, pt. II.

⁶ The Ore Deposits of the Cobalt District, Ont., by C. R. Van Hise, Jour. Can. Min. Inst., 1907, Vol. 10, pp. 45-61. The above is largely quoted word for word from the original article.

seated conditions when the waters were free from oxygen; during this first period arsenical, antimonial, and sulphur compounds of cobalt, nickel, and silver were deposited. He does not know whether these waters were atmospheric or magmatic, or partly one and partly the other. Since the first concentration there has been a second concentration through the influence of surface waters bearing oxygen and descending or travelling laterally. An adequate explanation of the ore deposits must combine the effects of the deep-seated and shallow circulations.

It appears that at least the major portion of the cobalt-bearing minerals, smaltite and cobaltite, are products of an early concentration. These minerals were doubtless deposited at a considerable depth below the surface. At this time the openings were largely or altogether filled with vein material, smaltite, cobaltite, and gangue materials.

After the main deposition of the cobalt minerals, there were movements which resulted in secondary fracturing of the veins. These openings permitted the entrance of silver-bearing solutions and the contact of these solutions with the cobalt minerals resulted in the precipitation of the silver. It is a well-known fact that if silver solutions are placed in contact with cobalt and nickel sulphides and arsenides under ordinary conditions, these minerals will precipitate the silver. Thus he inclines to the view that the cobalt minerals appeared comparatively early, and that later the silver-bearing solutions appeared, which resulted in the silver minerals. In presenting this view he does not mean to say that the deposition of the cobalt minerals had ceased before the silver began to be deposited, for the two may have overlapped to a considerable extent.

It appears certain that the extremely rich, superficial deposits of a few feet in thickness, connected with the zone of weathering, are due to secondary concentration under surface conditions. This statement refers to the nugget horizon which is so rich in silver and in which the smaltite and cobaltite have been largely altered into secondary minerals, or have been leached out altogether. It is practically certain that this extraordinarily rich upper film in the Cobalt area has been produced by two concentrations, one under deep-seated conditions when atmospheric waters were not present, and the other under surface conditions when atmospheric waters were present.

Van Hise points out that it must be remembered that in the past the veins which now stop abruptly at the surface continued upward to an unknown height into what is now the atmosphere. Erosion has cut away this upper material. This process has been a very slow one. At any given time the silver salts at or near the surface were being oxidized to a soluble form and were being carried down in the openings of the veins. At or near the level of groundwater the silver in the solutions would again be precipitated by the cobalt minerals. These reactions would take place with the arsenical and antimonial silver-bearing minerals as well as with argentite, although the latter case is more simple. The argentite in the upper part of the belt is oxidized to silver sulphate which is readily soluble. As this salt is carried down and comes in contact with the cobalt minerals, native silver is precipitated, just as silver is precipitated from silver sulphate in a beaker when in contact with such minerals.

As the process of erosion, solution, and deposition goes on, the material, once enriched as the result of erosion, reaches the surface and goes through the same process as before. In this manner, a layer of rich material is accumulated at the surface. Thus the nugget zone is produced.

But the majority of the mines do not depend upon this very rich superficial film, but upon the main horizon below. To what extent is this deeper horizon the result of a single concentration under deep-seated conditions and of a later

concentration under surface conditions? To this question he is unable to give a definite answer, but he believes that the later secondary concentration, even for this belt, has made important additions to the silver values and may have been an important factor throughout the horizon. Whether the chief values of silver are thus explained or were produced under deep-seated conditions in the later stages of the Cobalt deposition, is a point for the future to decide.

He believes the diabase is the source of the ore. The diabase sheet cooled first along the contacts. Consequently, when the main mass was still molten the exterior was solid. During cooling, contraction took place, earth movements occurred, and openings were found not only in the conglomerate and Keewatin, but in the solidified diabase itself. Later, when these openings became filled by deposits from circulating solutions, they formed the veins of the area. Thus openings in the outer solid part of the diabase may be filled with silver-bearing solutions which are derived from the diabase itself. If this theory is correct, what would be expected as to the distribution of the ore-bearing veins? He imagines that the diabase would be most likely to bear productive veins in contact with or close to the older rocks because these are the parts first cooled. If this theory is correct, veins should be found in the conglomerate and Keewatin in those parts of these formations which are close to the diabase.

He believes that the Keewatin and conglomerate are the main sources of the calcite of the veins.

He suggests that the solutions bearing calcium carbonate were a factor in the precipitation of the metalliferous minerals. It is probable that precipitation was largely caused by the mingling of solutions which were derived from the diabase, Keewatin, and conglomerate, although the mere cooling of the solutions may have been a factor in the process.

He suggests that the favourable places to explore are those in the conglomerate and Keewatin along the border of the diabase; and the favourable place in the diabase itself is comparatively near its border.

Present knowledge warrants cautious attempts to explore the conglomerate below the diabase for silver veins. If the conglomerate under the diabase proves to be profitable, it will furnish information as to the relative importance of the primary and secondary concentrations; for the ores below the diabase will be largely those produced by the deeper circulation, and comparatively little affected by the secondary concentration.

Following the presentation of this paper by Van Hise, a discussion took place in which Messrs. Ingall, Hixon, Parks, Van Hise, Coste, Bell, Miller, Tyrrell, and Brock took part. In replying to some questions, Van Hise said he did not know how much of the silver was deposited by the secondary surface concentration nor what proportion was produced under deep-seated conditions.

Miller said he did not think there was any question at all that there were two periods of deposition. Miller also discussed an important feature of the veins. He gave reasons why the silver in the veins disappeared when the veins passed down into the Keewatin rocks. There are a number of veins which pass from the conglomerate down into the Keewatin. They hold their width pretty well in passing—not all, but some of them. Now in practically all cases, that is in the area west of Peterson lake, the silver values disappear when they go to the Keewatin, but the smaltite and niccolite continue below the contact. The only explanation he could give for this was that during this period of secondary disturbance the silver filled in the cracks through the smaltite or other minerals. The silver is always found in the secondary cracks; but during this period of

secondary disturbance, the Keewatin being the older mass, the igneous formation differing from the conglomerate seems to have escaped the effects of this slight disturbance, hence there were no cracks in it, and the solutions could not get through the Keewatin. They could work through the vein in the over-lying conglomerate, but the vein in the Keewatin escaped. It seemed to him that this was pretty conclusive evidence of two periods of deposition: an older period of deposition of nickel and cobalt minerals, and a later period of deposition of silver minerals. Referring to the question of carbonaceous material, Miller said that there was considerable graphite in one of La Rose veins. There is also much graphite in the Cobalt hill vein, a massive vein of smaltite and niccolite 14 inches wide, where there is no silver at all.

Ledoux,¹ in 1907, shows the grade of the Cobalt ores as determined at his sampling works in Jersey City. Since January, 1905, he has handled at the works, 366 carload lots of ore and 52 other lots, less than carloads, including what are called nuggets. The nuggets are not pure silver, but run anywhere from 700 to 870 parts of silver in the thousand. There are more or less gangue and other materials associated with the silver, and the metallic silver itself, visibly free from gangue, runs about 950 fine. Leaving out of consideration the nuggets and native silver and including only the lots of regular ore, a review of 394 lots sampled shows that the highest lot ran 7,402 ounces of silver to the ton, the next in order being 6,909, 6,413, 6,163, and 5,948 ounces per ton. In the 394 lots he found that 40 per cent. of the lots contained from 1,000 to 7,402 ounces of silver to the ton. The highest per cent. of cobalt found in any one shipment is 11.96 per cent., the average being 5.99 per cent. The highest assay for nickel in any car is 12.49 per cent., the average being 3.66 per cent. The highest per cent. of arsenic is 59.32 per cent., the average 27.12 per cent.

Bell,² in 1907, gives a general account of the rocks and veins at Cobalt.

Tyrrell,³ in 1907, concludes that the cobalt and silver veins were formed in V-shaped fissures which taper from above downwards; that, although they were formed by mineral-bearing waters which rose from deep-seated sources, and were associated with the latest stages of the eruption of diabase, having probably risen through the same vents with it, these waters spread out laterally through cracks and openings in the mushroom-shaped top of the laccolith of diabase and descended into the fissures in the rocks beneath it; that the veins were thus originally formed by deposition from waters which locally descended from above, rather than ascended from below, as in most normal veins; and finally that the veins were superficially enriched at a later period by atmospheric waters descending through portions of the veins which have since been eroded away.

Miller,⁴ in 1907, publishes the third edition of his report on Cobalt. This edition has been enlarged. More detailed descriptions are given as to the character of the rocks. A chapter on the working mines of Cobalt has been added by E. T. Corkill, and also a chapter on the Montreal River area and South Lorrain by Cyril W. Knight. A description of the Bloom Lake area is given by W. R. Rogers, and a report on Casey and Harris townships, and Wendigo lake by R. E. Hore. Mr. J. S. DeLury describes an area west of Bay lake.

¹ Richness of Cobalt Ores, by Albert R. Ledoux, Jour. Can. Min. Inst., 1907, Vol. 10, pp. 62-68.

² The Cobalt Mining District, by Robt. Bell, Jour. Can. Min. Inst., 1907, Vol. 10, pp. 62-68.

³ Vein Formation at Cobalt, Ontario, by J. B. Tyrrell, Can. Min. Jour., Aug. 1, 1907, pp. 301-303.

⁴ Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming, by Willet G. Miller, Ont. Bur. Mines, Vol. XVI., 1907, pt. II.

Gibson,¹ in 1907, gives an account of the first discoveries of silver at Cobalt. He says:—

The discovery of the Cobalt silver camp was one of the most significant events in the story of the mining industry of Ontario. The region was not a remote one, being close to the shores of Lake Temiskaming whose waters were known to the voyageurs of two centuries ago, and was in later times for years the scene of active lumbering operations, yet its mineral riches, though in many places lying actually on the surface, remained undiscovered until accidentally stumbled upon in the summer or fall of 1903.

The first discovery seems to have been made by James H. McKinley and Ernest J. Darragh, described as "lumbermen and prospectors," who on 14th August, 1903, made a joint application to the Department of Crown Lands for a location situated "about 600 feet southeasterly from the ninth mile, say between stations 54 and 64, south from New Liskeard, of the Temiskaming and Northern Ontario Railway line as now located and graded." The application was not accompanied by the required affidavit showing discovery of mineral, but this was supplied on 6th October, and gave the date of discovery as the 7th August previous, the find consisting of rock ascertained by assay to contain "a goodly percentage of free or native silver." According to the papers, McKinley and Darragh were joint discoverers. The location was surveyed by W. J. Blair, O.L.S., as J.B. 1, containing 32 acres. Subsequently, four acres of the bed of Cobalt (then known as Long) lake in front of J.B. 1, and the mining rights of the road allowance between these two parcels, containing two acres, were granted. The discovery on J.B. 1 was developed into the well-known McKinley-Darragh mine, now owned and operated by the McKinley-Darragh-Savage Mining Company.

While silver appears to have been the first mineral of value actually discovered in Cobalt, the active history of the camp begins with the finding of niccolite (kupfer-nickel) on what is now the La Rose mine, perhaps the most famous of all the Cobalt deposits. Fred La Rose, a blacksmith employed in construction work on the T. & N. O. railway, then being graded, when not engaged in sharpening "steel" for the rock-men, was accustomed to poke about the rocks in the neighbourhood of his smithy. In doing so he uncovered some pinkish material and a little digging disclosed samples of a heavy copper-coloured mineral, which in reality was niccolite, hitherto found in Ontario only in minute quantity, and known practically in this Province to mineralogists only. La Rose applied to the Department on 29th September, 1903, for a location described as being opposite station 113 on the T. & N. O. railway about 1,300 feet from Long lake at the mouth of Rock creek about one mile from the south boundary of the township of Bucke. The date of the discovery is given in the affidavit as 15th September, 1903. The claim was afterwards surveyed by John Shaw, O.L.S., as J.S. 14, containing 37 acres, being a 40-acre tract less the right of way of the T. & N. O. railway which crosses the western half of the parcel almost diagonally. La Rose's affidavit (which is signed Fred "Rose") describes his discovery as of one of copper, which was not an unnatural mistake under the circumstances, especially as La Rose was not a prospector, and knew nothing whatever about minerals. Neil A. King, a fire ranger on the T. & N. O. line, subsequently (on 8th October, 1903) filed a claim for 160 acres, being "80 acres south of lot 8 first range township of Bucke, also 80 acres south of lot 9 first range" of said township, a description which included the La Rose parcel. King dated his discovery on 16th May, 1903, also describing the mineral found as "copper ore." A hotly contested dispute between La Rose and King—or their assignees—followed, which was decided in favour of La Rose. The latter and his associates had at first entirely failed to recognize the native silver which lay blackened by exposure in plates and nuggets on the surface of the vein, both in place and in the form of boulders. These were pointed out to them by Prof. Miller, Provincial Geologist, who visited and examined the veins in the early part of November, 1903. Mr. Miller's reports really made known these remarkable discoveries to the public.

Coleman,² in 1907, extracted from the conglomerate at Cobalt a few stones showing well marked striations, confirming a conclusion which he had reached some time before that the Lower Huronian conglomerate is an ancient boulder clay.

Barlow,³ in 1908, discusses the origin of the silver in James township in the Cobalt area. He regards the vein filling as of pegmatitic origin, having the same genetic relationship to diabase that ordinary pegmatite has to granite. He prefers the term diabase-pegmatite in preference to the term aplite. Some of the veins are made up almost wholly of red feldspar, which is almost always a plagioclase near the acid end of the series, together with a subordinate amount of calcite and quartz. The quartz sometimes forms graphic intergrowths with the

¹Thos. W. Gibson, *Ont. Bur. Mines*, Vol. XVI., pt. I, p. 7.

²*Am. Jour. Sci.*, Vol. 23, 1907, pp. 187-192.

³*The Origin of the Silver of James Township, Montreal River*, by Alfred E. Barlow, *Jour. Can. Min. Inst.*, 1908, Vol. 11, pp. 256-273.

feldspars. Other veins are made up of an almost equal proportion of plagioclase and calcite and sometimes quartz, while still others present a finer-grained feldspathic portion in the vicinity of the walls, with the whole mass of the interior made up of coarse-grained calcite and sometimes a little quartz.

Hore,¹ in 1908, suggests that the arsenides and sulphides of the Cobalt veins have been concentrated from the diabase magma by extreme differentiation.

Tyrrell,² in 1908, discusses Barlow's paper³ on the origin of silver in James township, and Hore's paper on Cobalt.⁴

Knight and Bartlett,⁵ in March, 1908, give the first description of the Keeley and Haileybury Silver (Frontier) mines in South Lorrain. There is an open cut 40 feet long and 14 feet deep, exposing a vein two to six inches wide on the Keeley. Smaltite and wire silver in what appear to be considerable quantity are present. At the Haileybury Silver claim a shaft had been sunk 40 feet on a vein which at the bottom showed five or six inches of smaltite and niccolite. The rock in the vicinity of the Keeley and Haileybury Silver veins belongs to the Keewatin series.

Coleman,⁶ in 1908, comes to the conclusion that the basal conglomerates of the Lower Huronian (Cobalt series) of the Cobalt area are consolidated tillites or ancient boulder clays. This shows that a glacial period existed at that time. Specimens of striated pebbles have been found by him in the conglomerate.

Barlow,⁷ in 1909, further discusses the veins in James township. He finds⁸ that while many of the veins or dikes are abruptly differentiated from the associated diabase, exhibiting perfectly sharp and in some cases free walls, others show a gradual transition from the vein material (pegmatite) into the surrounding diabase, which graduation can only be explained on the assumption of a commingling of material while both were in a fluid, or, at most, a viscous condition, and before complete solidification has taken place. Not only the native silver, but also the characteristic sulphides and arsenides began to be introduced along with the first pegmatite (aplite) filling. These metallics did not wait for the reopening of the pegmatite and the introduction of more abundant calcite, for the latter mineral accompanied and overlapped the crystallization of the feldspar. He considers the pegmatites to be the ore bringers.

The use of the terms "dike" and "vein" as separate names in regard to pegmatite is misleading. The strict limitation of their meaning has led to certain misconceptions as to its manner of formation. He would prefer to make the two terms synonymous, or better still to use "vein" in both senses, for, accurately speaking, every "mineral vein" is intrusive in the surrounding country rock.

Tyrrell,⁸ in 1909, discusses the origin of the mineral veins in the Montreal River area.

¹Origin of the Cobalt-Silver Ores of Northern Ontario, by R. E. Hore, Jour. Can. Min. Inst., Vol. 11, 1908, pp. 275-286.

²Mineral Veins in the Montreal River District, by J. B. Tyrrell, Can. Min. Jour., Dec. 15, 1908, pp. 651a-652a.

³The Origin of the Silver of James Township, by Alfred E. Barlow, Jour. Can. Min. Inst., Vol. 11, 1908, pp. 256-273.

⁴Origin of Cobalt-Silver Ores of Northern Ontario, by R. E. Hore, Jour. Can. Min. Inst., Vol. 11, 1908, pp. 275-286.

⁵Cobalt-Silver Veins, South Lorrain, by Cyril W. Knight, Ont. Bur. Mines, Vol. XVI., 1907, pt. II, p. 147.

⁶The Lower Huronian Ice Age, by A. P. Coleman, Jour. Geol., Vol. 16, 1908, pp. 149-158.

⁷Mineral Veins in the Montreal River District, by Alfred E. Barlow, Can. Min. Jour., Jan. 15, 1909.

⁸Mineral Veins in the Montreal District, by J. B. Tyrrell, Can. Min. Jour., Mar. 1, 1909, p. 149.

Coleman,¹ in 1909, describes the Pleistocene geology in northeastern Ontario, with special reference to the Glacial lake Ojibway. Mention is made of the Pleistocene deposits along the Temiskaming and Northern Ontario railway.

Bowen,² in 1909, gives analyses of three aplite dikes from the Cobalt silver field and shows that the aplites have a simple mineral composition.

Collins,³ in 1909, gives a preliminary report on Gowganda.

Bowen,⁴ in 1909, describes the aplites and diabase of the Cobalt area.

Ramsay,⁵ in 1909, gives a brief description of the rocks and veins in the Maple Mountain area.

Mickle,⁶ in 1910, discusses the probable number of veins in the Cobalt district. At the close of July, 1907, there appeared to be in all sixty-six different productive veins. These were distributed among the geological formations as follows:—

Huronian (Cobalt series).....	53
Diabase.....	7
Keewatin.....	6

Hore,⁷ in 1910, discusses the diabase of the Cobalt area.

Hore,⁸ in 1910, discusses the Huronian rocks of Nipissing, Ontario.

Collins,⁹ in 1910, describes the quartz-diabase of Nipissing district.

Bowen,¹⁰ in 1910, describes the diabase and granophyre of Gowganda. He ascribes the red and pink colour of the plagioclase to thin plates of hematite filling the cleavage spaces.

Wilson,¹¹ in 1910, reports on an area adjoining the east side of Lake Timiskaming, Quebec. He finds that the geology differs but slightly from the Timagami-Timiskaming area, presenting rocks of the same varieties and in the same stratigraphical relationship. He finds, however, no unconformity in the Huronian (Cobalt) series between the conglomerate and greywacké, and the overlying quartzite and arkose.

The diabase, with which the silver-cobalt ores of the Timiskaming area are associated, has its largest extent in the township of Fabre. This diabase is poorly exposed and prospecting is thus rendered difficult. No silver deposits of economic value have been found.

¹Lake Ojibway, Last of the Great Glacial Lakes, by A. P. Coleman, Ont. Bur. Mines, Vol. XVIII, 1909, pp. 284-293.

²Composition of the Aplites, by N. L. Bowen, Can. Min. Jour., April 15, 1909, p. 240.

³Preliminary Report on Gowganda Mining Division, by W. H. Collins, Geol. Surv. Can., 1909, pp. 47.

⁴Diabase and Aplite of the Cobalt Silver Area, by N. L. Bowen, Jour. Can. Min. Inst., Vol. 12, 1909, pp. 517-528.

⁵The Maple Mountain Mining District of Ontario, by J. D. Ramsay, Can. Min. Jour., Sept. 1, 1909, pp. 526-527.

⁶The Probable Number of Veins in the Cobalt District, by Geo. R. Mickle, Jour. Can. Min. Inst., Vol. 13, 1910, pp. 325-335.

⁷Diabase of the Cobalt District, Ont., by R. E. Hore, Jour. Geol., Vol. 18, No. 3, April-May, 1910.

⁸Huronian Rocks of Nipissing, Ontario, by R. E. Hore, Jour. Geol., Vol. 18, No. 5, July-Aug., 1910.

⁹Quartz-Diabase of Nipissing District, by W. H. Collins, Econ. Geol., Vol. 5, No. 6, Sept., 1910, pp. 538-550.

¹⁰Diabase and Granophyre of the Gowganda Lake District, Ont., by N. L. Bowen, Jour. Geol., Vol. 18, No. 7, Oct.-Nov., 1910, pp. 658-674.

¹¹Geology of an Area Adjoining the East Side of Lake Timiskaming, Quebec, by Morley E. Wilson, Geol. Surv. Can., Publication No. 1064.

Coleman,¹ in 1910, summarizes again his reasons for believing that there was an ice age in Lower Huronian times. He notes that Willet G. Miller, in 1905, had guardedly suggested the resemblance of the conglomerate to boulder clay.²

Miller and Knight,³ in 1911, discuss the Laurentian system.

Harvie,⁴ in 1911, geologically maps and reports on the township of Fabre, Quebec, on the east side of Lake Timiskaming and opposite South Lorrain. He finds that the geological sequence in Fabre is very similar to that of Cobalt, but is fuller, since another Huronian series, not known at Cobalt, is present. This series he names the Fabre series. It is closely associated with the Keewatin, and also somewhat squeezed. It is a thin succession of conglomerate, arkose, quartzite, and greywacké, which represent the lowest series of Huronian found in the area. This series lies below and is essentially different from the Lower Huronian (Cobalt series) described by Miller at Cobalt. The relations to the Laurentian are not as well known, the sediments being older than some of the dike rocks and younger than others.

He finds that numerous cobalt-bearing quartz-calcite veins, with a few aplite dikes, are found in the diabase. None of these veins contain economic quantities of silver. A little gold occurs in the veins. Some of the veins have been found in the Keewatin, but none in the Huronian. He believes there is no great promise in the mineral deposits of Fabre.

Miller,⁵ in 1911, proposes to employ the name Cobalt series for the fragmental series in which the cobalt-silver veins characteristically occur at Cobalt. The name Timiskaming will be used for the older, more disturbed conglomerate series which outcrops at Kirk and Cross lakes and in greater volume on Lake Timiskaming, outcrops also being known a considerable distance south of Cobalt and 90 miles to the northwest at Porcupine. The granite intruding in the Timiskaming series but not in the Cobalt series, will be called the Lorrain granite, a name under which it is already known. The quartz-diabase of the sill at Cobalt, which is of such great economic importance and is so widespread not only in that vicinity, but throughout a large territory in the district of Nipissing, will be called the Nipissing diabase. This will serve to distinguish it from diabase of other ages that occur in the region.

Miller finds that faults, generally with small displacement, and joints are very numerous in rocks in which the Cobalt ores are found. Few drifts are run that have not one smooth wall, indicating a fault or a joint for at least part of their course. The faults are of various ages. Some of those in the Keewatin are doubtless pre-Huronian in age. Others were formed at the time of the Lorrain granite intrusion; while later faulting took place at the time of the intrusion of the diabase sill and later still when the fissures now occupied by the ores were opened. After the filling of the veins, there was again faulting in pre-Cambrian times. A few veins occupy fault planes while others have been disturbed by more recent faulting. There were even minor faults that were formed after the glacial period.

¹The Lower Huronian Ice Age, by A. P. Coleman, Internat. Geol. Congr., 1910.

²Ont. Bur. Mines, Vol. XIV, 1905, p. 41.

³The Laurentian System, by Willet G. Miller and Cyril W. Knight, Ont. Bur. Mines, Vol. XX, pt. I, pp. 280-284.

⁴Geology of Portion of Fabre Township, Pontiac County, by Robert Harvie, Mines Branch, Quebec, 1911. See also re Fabre series, Ont. Dept. Mines, No. 62, Vol. XIX, pt. 11.

⁵Notes on the Cobalt Area, by Willet G. Miller, Eng. and Min. Jour., Sept. 30, 1911, pp. 645-649.

Hore,¹ in 1911, reviews the geology of the Cobalt area.

Hore,² in 1911, reviews the geology of Cobalt.

Hore,³ in 1911, discusses differentiation in the quartz-diorite of the Cobalt area.

Mickle,⁴ in 1912, estimates a probable total production of silver from Cobalt of 242 million ounces.

Up to July, 1911, there appeared to be 111 veins that could be considered productive; these were distributed among the geological formations as follows:—

Huronian (Cobalt series).....	86 veins, or 77.5 per cent.
Diabase.....	12 veins, or 10.8 per cent.
Keewatin.....	13 veins, or 11.7 per cent.

The diorite has yielded 7 per cent., the Keewatin 10.85 per cent., and the Cobalt series 82 per cent. of the total production.

Knight,⁵ in 1912, compiles ten cross-sections showing the structure of the rocks in the Cobalt area proper. He finds that the Cobalt lake fault has a vertical displacement of 233 feet at La Rose mine, while at the McKinley-Darragh it is possibly 400 feet or more.

Colvocoresses,⁶ in 1912, finds at the Millerett mine that silver ore occurs in the No. 1 vein in the Huronian above the diorite sill. The top of the sill dips eastward at 30°.

He points out that in Gowganda all of the producing veins have been found in the diorite or (in one case) in the Huronian rocks above the diorite sill. Nothing has been found in the foot-wall of the diorite sill.

Very little prospecting has ever been done in the Huronian conglomerate, but he believes there is every reason to assume that some good conglomerate veins yet remain to be discovered. The Miller Lake-O'Brien vein in diorite had not a remarkable surface showing, nor did the mine look particularly promising until after a year's hard work.

Palmer and Bastin,⁷ in 1913, in preliminary experiments show that certain sulphides and arsenides of copper and nickel, precipitate metallic silver very efficiently from dilute aqueous solutions of silver sulphate. The more common sulphides, such as pyrite, galena, and sphalerite, were relatively inactive as precipitants of silver from aqueous solutions of its sulphate.

Tyrrell,⁸ in 1913, points out that as a general rule in South Lorrain the veins appear to be near the contact between the diorite and the Keewatin, either in the diorite itself or in the Keewatin greenstone. In South Lorrain the conglomerates do not appear to have been attractive to the silver-bearing solutions. The rich ore-bodies, where they occur, are not found directly at the diorite contact, but at some little distance away from it.

¹Geology of the Cobalt District, Ont., Canada, by R. E. Hore, Trans. A.I.M.E., Vol. 42, 1911, pp. 480-499.

²The Silver Fields of Nipissing, by R. E. Hore, Jour. Can. Min. Inst., Vol. 14, 1911, pp. 612-636.

³Differentiation Products in Quartz-Diorite Masses of the Cobalt District, by R. E. Hore, Econ. Geol., Vol. 6, No. 1, 1911, pp. 51-59.

⁴The Probable Total Production of Silver from the Cobalt District, by Geo. R. Mickle, Jour. Can. Min. Inst., 1912.

⁵Recent Underground Development Work at Cobalt, by Cyril W. Knight, Trans. Can. Min. Inst., Vol. 15, 1912, pp. 231-237.

⁶Gowganda during 1911, by G. M. Colvocoresses, Can. Min. Jour., April 15, 1912, pp. 256-260.

⁷Metallic Minerals as Precipitants of Silver and Gold, by Chase Palmer and Edson S. Bastin, Econ. Geol., March, 1913.

⁸Silver Veins of South Lorrain, by J. B. Tyrrell, Can. Min. Jour., June 1, 1913, pp. 329-330.

Miller and Knight,¹ in 1913, referring to northern Ontario, are inclined to place the Keewatin jaspilite and other sediments associated with it, such as greywacké and crystalline limestone, with the Grenville series. They consider that the dual grouping of the pre-Cambrian should be discarded.

It is not at all unlikely that the diabase and norite of Cobalt and Sudbury, respectively, are of the same age as the Keweenawan basic igneous rocks of Michigan and the Lake Superior country generally.

Miller,² in 1913, summarizes the geology of the Cobalt area. This is largely a summary of Miller's fourth edition of his report on Cobalt.

Collins,³ in 1913, divides the rocks in Gowganda into the following divisions:—

PRE-CAMBRIAN...	Pleistocene.....	{ Unconsolidated glacial till, stratified clay and sand.
		<i>Great unconformity.</i>
	Post Huronian intrusions.....	{ Olivine diabase. Quartz diabase and aplite.
	Huronian.....	{ Upper or Middle. Quartzite, arkose, and quartz conglomerate (Lorrain series). <i>Faint unconformity.</i>
		{ Middle or Lower. Conglomerate, greywacké, slate, and arkose (Cobalt series).
		Rhyolite, lava and tuff.
		<i>Great unconformity.</i>
	Laurentian batholithic intrusions.....	{ Hornblende and biotite granites, granodiorite and syenite and their gneissic equivalents.
	Keewatin.....	{ Basic and acid volcanic and intrusive rocks, chloritic and sericitic schists, iron formation, graphitic slate and hornblende schist.

Collins finds that the silver deposits form veins, commonly less than a foot wide, either within the diabase or, in a few cases, in the formations immediately adjacent. These consist of a quartz and calcite, less frequently barite, gangue carrying native silver, smaltite, niccolite, chalcopryrite, and smaller amounts of native bismuth, argentite, galena, pyrite, specularite, and other minerals. Silver was deposited somewhat later than the other minerals and traverses them as a fine network. Erythrite and annabergite occur as oxidation products of smaltite and niccolite for a depth of a few feet beneath the surface. The ores are not evenly distributed through the veins, but occur, so far as present explorations indicate, in irregular masses. The diabase, for a few inches away from the veins, is often irregularly mineralized.

He regards the diabase masses as occurring in sills, and he gives an excellent description of their lithological character.

The aplite dikes which cut the diabase may be described as unusually fine-grained pink granite poor in dark minerals, but there are wide variations from such a type.

¹Sudbury, Cobalt and Porcupine Geology, by Willet G. Miller and Cyril W. Knight, Eng. Min. Jour., June 7, 1913, pp. 1129-1133.

²Guide Book No. 7, Internat. Geol. Congr., 1913.

³Geology of Gowganda Mining Division, by W. H. Collins, Geol. Surv. Can., Memoir No. 33.

Miller,¹ in 1913, publishes the fourth edition of his report on the cobalt-nickel arsenides and silver deposits of Timiskaming. This work of 279 pages, with detailed geological surface maps and plans, is the outstanding report on the area. On account of its size it is not practical to attempt to summarize it here. The report gives an account of the discovery of the veins, a description of the ores and minerals, a record of the dividends paid, an account of the rocks and their age relationships, and so forth. The report is still in print and may be obtained from the Ontario Department of Mines, Toronto. For convenience, however, Miller's subdivisions of the rocks are given below, together with his broad general comments thereon. In the following legend, Miller discontinues the use of the term Huronian which he had made use of in the first three editions.

The dual subdivision of the pre-Cambrian into Algonkian and Archean, or Proterozoic and Archeozoic, employed by many authors, is not adopted by the writer, since he believes that the Grenville series, which includes limestones and other sediments of great thickness, is of pre-Laurentian age. The thickness of the sediments in the Grenville and the character of the deposits make it inadvisable to attempt to subdivide the pre-Cambrian into an upper characteristically sedimentary group, above the Grenville, and a lower igneous complex including the Grenville sediments. The subdivision into Proterozoic and Archeozoic groups, the latter including the Grenville, is purely arbitrary. Thus a dual subdivision of pre-Cambrian rocks, based on arguments that have been employed in its behalf, fails. If a name is desired for the pre-Cambrian rocks, to correspond with Paleozoic and Mesozoic, the well-known name Eozoic may be used.

AGE RELATIONS OF ROCKS OF COBALT AND ADJACENT AREAS

PALEOZOIC

SILURIAN Niagara

Prominent outcrops of Niagara limestone, with basal conglomerate and sandstone, occur on some of the islands and the shores of the north end of lake Temiskaming.

(*Great unconformity*)

EZOIC OR PRE-CAMBRIAN

LATER DIKES

Aplite, diabase, basalt.

NIPISSING DIABASE (*Intrusive contact*)

This diabase, which is of such great interest in connection with the cobalt-silver veins, is believed to be of Keweenawan age. Certain aplite dikes are genetically connected with the diabase.

COBALT SERIES (*Unconformity*)

The Cobalt series includes conglomerate, greywacké and other fragmental rocks.

LORRAIN GRANITE (*Intrusive contact*)

This granite occupies a considerable part of the township of Lorrain and has large exposures elsewhere in the vicinity of lake Temiskaming.

LAMPROPHYRE DIKES (*Intrusive contact*)

Lamprophyre dikes are to be seen near some of the mines at Cobalt.

TEMISKAMING SERIES (*Unconformity*)

Like the Cobalt series, the Temiskaming consists of conglomerate and other fragmental rocks.

KEEWATIN COMPLEX

The Laurentian, gneiss and granite, which in age lies between the Keewatin and Temiskaming, is absent in the Cobalt area proper, but is found in the surrounding region.

Under the heading Keewatin are grouped the most ancient rocks of the region. They consist essentially of basic volcanic types, now represented by schists and greenstones, together with more acidic types, such as quartz-porphyry.

With the Keewatin are included certain sediments, such as iron formation or jaspilite, dark slates and greywackés, which probably represent the Grenville series of southeastern Ontario.

Certain dike rocks that are grouped with the Keewatin may be of post-Temiskaming age, but since they have not been found in contact with the Temiskaming their age relationships are unknown.

¹ The Cobalt-Nickel Arsenides and Silver Deposits of Timiskaming, by Willet G. Miller, Ont. Bur. Mines, Vol. XIX, pt. II, 1913.

Livermore,¹ in 1914, gives a description of the method and machinery used in draining Kerr lake, Cobalt.

Williams,² in 1915, determines from fossils collected that the dolomites west and north of Haileybury are of Black River age; that the upper strata of Mann island and the top of Farr island belong near the base of the Niagara; that the Dawson point section includes besides undetermined beds at the base, the Niagara from its base to the horizon of numerous corals; that Chief island contains in the patches of limestone resting upon the Huronian, representatives of both Niagara and Trenton rock; that a limited area of Silurian strata occurs north of the wharf at Haileybury; and that the green calcareous shales making up the lower part of the section at the northwestern end of Mann island and probably concealed by talus on the eastern side of Dawson point, must be between Black River and Niagara in age.

Miller and Knight,³ in 1915, present a detailed classification of the pre-Cambrian ore deposits in the Province of Ontario, showing the various metallogenetic epochs into which the period may be divided. The following table shows that there have been at least four great metallogenetic epochs during the pre-Cambrian period in Ontario, namely, Grenville, Algoman, Animikean, and Keweenawan. A fifth epoch of minor importance should probably be added to represent the ore-bodies associated with the basic intrusives that preceded the intrusion of the Algoman granite and followed the deposition of the Timiskaming sediments.

The basic rocks of the Keweenawan in Michigan and in the Coppermine River country are considered to be genetically connected with deposits of native copper. In Ontario, along the north shore of Lake Huron, the Keweenawan intrusives appear to have given rise to the deposits of copper pyrites, while at Sudbury the copper-nickel ores and at Cobalt the silver-cobalt veins have been shown to be genetically connected with them.

AGE CLASSIFICATION OF ONTARIO ORE DEPOSITS

Keweenawan—Epoch, following basic intrusions, of (a) Silver, cobalt, nickel and arsenic at Cobalt and elsewhere, (b) Nickel and copper at Sudbury, and copper elsewhere. Certain gold deposits, not now productive, appear to belong to this epoch.

Animikean—Epoch of deposition of "iron formation" as a chemical precipitate.

Algoman—Epoch, following granite intrusions, of gold at Porcupine and at many other localities, and of auriferous mispickel. Deposits of galena, zinc blende, fluorite and other minerals also appear to have been derived from the granites, but some of them were not formed till post pre-Cambrian time. Preceding the intrusion of the Algoman granites, basic intrusives, that appear to be of post-Timiskamian age, gave rise to nickel and titaniferous and non-titaniferous magnetite deposits and chromite.

Timiskamian—Epoch of minor deposition of "iron formation" as a chemical precipitate.

Laurentian—Granite intrusions probably gave rise to ore deposits which have been removed by excessive erosion as is known to be the case with deposits of later origin.

Loganian—

Grenville—Epoch of deposition of extensive "iron formation" as a chemical precipitate among other sediments.

Keewatin—Composed largely of basic volcanic rocks.

Miller and Knight,⁴ in 1915, give a general discussion of the pre-Cambrian geology of Ontario and of the classification. They divide the rocks into the following subdivisions:—

¹ Draining Kerr Lake, by R. Livermore, Trans. A.I.M.E., Vol. 49, 1914, pp. 328-342.

² The Ordovician Rocks of Lake Timiskaming, by M. Y. Williams, Geol. Surv. Can., Mus. Bull. No. 17.

³ Metallogenetic Epochs in the Pre-Cambrian of Ontario, by Willet G. Miller and Cyril W. Knight, Trans. Roy. Soc. Can., Ser. III, 1915, Vol. IX.

⁴ Revision of Pre-Cambrian Classification in Ontario, by Willet G. Miller and Cyril W. Knight, Jour. Geol., Vol. 23, 1915, No. 7, Oct.-Nov.

KEWEENAWAN
Unconformity
ANIMIKEAN

Under this heading the authors place not only the rocks that have heretofore been called Animikie, but the so-called Huronian rocks of the "classic" Lake Huron area, and the Cobalt and Ramsay Lake series. Minor unconformities occur within the Animikean.

Great unconformity
(ALGOMAN granite and gneiss)
Igneous contact
TIMISKAMIAN

Laurentian of some authors, and the Lorrain granite of Cobalt, and the Killarney granite of Lake Huron, etc.

In this group the authors place sedimentary rocks of various localities, that heretofore have been called Huronian, and the Sudbury series of Coleman.

Great unconformity
(LAURENTIAN granite and gneiss)
Igneous contact

There is no evidence that this unconformity is of lesser magnitude than that beneath the Animikean.

LOGANIAN {
Grenville
(Sedimentary)
Keewatin
(Igneous)

The authors have found the Keewatin to occur in considerable volume in southeastern Ontario and have determined the relations of the Grenville to it.

Hume,¹ in 1916, maps an area of Paleozoic sediments extending from the north end of Lake Timiskaming northward to Englehart. The chief change in the geological map of the area was made in the region extending northwest from New Liskeard; this part had previously been mapped as pre-Cambrian, but from drill records available it was found that the rock is Paleozoic limestone, Lockport in age. He finds that the Paleozoic rocks may be subdivided as follows:—

Lockport and Cataract formations, Silurian in age, including some basal conglomerate and sandstone of Ordovician age.
Black River—Trenton, Ordovician in age.

Reference is made to the Lake Timiskaming fault.

Ellsworth,² in 1916, makes a chemical study, combined with a microscopic examination of polished surfaces of certain minerals from Cobalt. He identifies four new minerals, namely, löllingite, rammelsbergite, chalcocite, and symplecite. He finds the order of deposition of the minerals to agree in the main with the conclusion reached by W. G. Miller and C. W. Knight.

From the numerous extremely intimate intergrowths which have been observed among the Cobalt minerals, e.g., smaltite-chloanthite, niccolite-breithauptite, etc., he believes that certain of these minerals were precipitated in greater or less quantity at the same time.

The structures observed appear to indicate that the mineralizing solutions at first were relatively very rich in arsenic and during this time intergrowths of diarsenides—smaltite and chloanthite—were chiefly precipitated. The arsenic content of the solutions gradually diminished and monarsenides—niccolite and breithauptite—were for a time predominately deposited. The arsenic continued to decrease in amount and sulphur became prominent, so that sulpharsenides, such as cobaltite and arsenopyrite, were deposited. Finally, the arsenic in solution was reduced to a very small quantity, and calcite was deposited. A period of fracturing ensued and the solution which may now have been of either a sulphate or carbonate character circulated through the fractured veins. From this solution native silver and argentite were precipitated by the action of arsenides and calcite.

It is believed that the process of deposition of the various arsenides and sulpharsenides was more or less continuous, and that, though a period of maximum deposition for any one of these minerals may be distinguished, there is, nevertheless, no sharp dividing line between the different periods.

¹ Paleozoic Rocks of Lake Timiskaming Area, by G. S. Hume, Sum. Rept., Geol. Surv. Can., 1916, pp. 188-192.

² A Study of Certain Minerals from Cobalt, Ontario, by H. V. Ellsworth, Ont. Bur. Mines, Vol. XXV, pt. I, 1916.

The apparent order of deposition from the writer's observations may be indicated in tabular form as follows:—

I. Arsenides and Sulpharsenides	1. Diarsenides	$\left\{ \begin{array}{l} \text{Ni As}_2 \\ \text{Co As}_2 \end{array} \right.$
	2. Monarsenides	$\left\{ \begin{array}{l} \text{NiSb} \\ \text{NiAs} \end{array} \right.$
	3. Sulpharsenides	$\left\{ \begin{array}{l} \text{Co As S} \\ \text{Fe As S} \end{array} \right.$

II. Calcite, followed by fracturing.

III. Native silver and argentite, native bismuth, sulphides and sulpho-salts.

IV. Decomposition products—arsenates of cobalt, nickel, iron, copper, and calcium.

Whitman,¹ in 1916, after a close study of many of the underground workings at Cobalt, concludes:—

That the ore bodies in the Huronian lie wholly within it and chiefly near the base.

That the ore bodies in the Keewatin lie chiefly within 300 feet of the upper or lower contact of the diabase.

That the ore bodies in the diabase lie chiefly within 300 feet of its margins.

Faults.—That ore exists in all classes of faults of steep attitude, but is distributed in them according to their attitudes and the stresses extant during the period of deposition.

That ore bodies of importance were often formed in favourable fractures in the walls of faults paralleling or diverging from them.

That such faults are genetically related to the folds in the district, striking diagonally across them from east to west, or approximately paralleling their axes.

Folds.—That ore is to be found in economic quantities only in areas of strong folding.

That within such areas the most favourable sites for ore are the slopes of folds, and particularly the steeper ones.

That on these slopes the most favourable spots are minor folds, and that the most favourable of these are the small cross folds.

That veins in these situations tend to parallel the dips of the sides of those minor folds being influenced by the major ones similarly but to a less extent, or that the veins tend to cross the axes of the minor folds, save as they may tend to parallel the axes of certain minor anticlines or to parallel faults.

That these sites are the best for ore bodies, particularly when they are associated with contacts as discussed above, or with major faults.

That the slopes are better sites than the axes of major folds, because on the slopes the deformation is the greatest and the best opportunities are afforded for the circulation and deposition of ore materials; and for the same reasons the steeper slopes are the better.

Joints.—That the fractures in which the ore bodies were formed were chiefly vertical joints produced by the compressive stresses which produced the folds and faults.

That such structural planes of weakness as contacts, slate beds, and major faults, together with the slopes of folds, constitute loci of strain and maximum jointing; and in such regions, particularly where two or more of them coincide, the vertical joints will have been converted into ore bodies.

That the joints in the Huronian are the most favourable seats of deposition, those in the diabase next, and those in the Keewatin least.

That the joints now open and uncemented express chiefly the final relief of the rocks from the original deformative stresses.

That the veins were formed under conditions of too great pressure for the existence of large open spaces or for the free opening of small fractures, and that they were formed by the metasomatic replacement of the walls of tight fractures.

Attitudes of Channels.—That of veins formed in joints, those that are the steeper are the richer, and the most flatly inclined are the poorer, under otherwise similar conditions, the richness being proportional to the degree of the dip, and the veins being thus classifiable with regard to both dip and contents:—

10° to 30°—Quartz, calcite, little sulphide.

30° to 50°—Quartz, calcite, much sulphide, little arsenide, trace of silver.

50° to 70°—No quartz, calcite, little sulphide, much arsenide, notable silver.

70° to 90°—No quartz, calcite, no sulphide, much arsenide, much silver.

That faults are not good seats of deposition for these ores, and that of faults with narrow shear zones the steeper side-thrust faults are most favourable, and in the wide shear zones of other faults, ores have formed only in spots locally relieved of compressive stress.

FAULTS

That the faults are all due to compression or to folding torsion.

That the east-west faults are side thrusts.

That the other faults are upthrusts or down thrusts.

That faults along folding axes on a given horizon dip with those axes.

¹ Final General Geological Report on the Area about Cobalt Lake, by Alfred R. Whitman, unpublished report, dated 1916.

That the side thrusts were the first faults, usually preceding the folding, that the folding torsion faults were next in age, and that the thrusts on the axial planes of folds were the last, but that the folding continues through all the faulting and after it, and the mineralization followed all the deformation

Whitman considers that discussion of the Keewatin-Huronian contact would not be complete without a description of its contour and its configuration in relation to the folds of the district.

On beginning his work, Whitman found that the contact between the Keewatin and Huronian was irregular and that some of the irregularities were abrupt. Some of the mine managers referred to Keewatin hills and valleys underlying the Huronian. There seemed to be an interesting prospect that the productive conglomerate could be forecast beneath the diabase in certain spots through the careful working out of old drainage systems carved in the Keewatin surface, in which Huronian gravels and finer sediments had been deposited.

Investigations were immediately started along this line; but it soon began to appear that the theory was untenable. The fact that the dips of the finer sediments conformed with the contact was at first admitted as consistent with the supposition that the first layers of sediment in a body of water would necessarily conform precisely with the sloping floor of the basin. However, it was recognized that this parallelism was not confined to the fine sediments lying on the Keewatin floor, but was also shared by those 100 feet or more above it, and by coarse boulder layers as well. These facts obviously could not be reconciled, and the idea of folding was adopted and subsequently proven.

The evidences in favour of folding are: (1) The interbedding of fine sediments with thick layers of heavy boulders, and the parallelism of the whole series to the contact for a distance of 100 feet and more from it. (2) The development of joints in the sediments as well as in the Keewatin and the diabase, parallel to the Keewatin-Huronian contact and showing evidences of shear in the direction of upthrust faulting on the sides of undulations. These flat-lying shear joints in many cases can be seen passing through pebbles in the Huronian conglomerate and faulting them short distances. Also in many cases these joints show distinct striae paralleling their dip. (3) Shearing on the contact itself.

The inference from this conformity of bedding with the contact is that the contact was virtually a horizontal plane when the sediments were laid down. And this by long careful research has been found to be the remarkable fact. There are a few exceptions to this rule: one of them is a small depression, perhaps 100 feet long by 150 feet wide and 25 feet in depth, lying on the west side of the Coniagas mine about one-third of the way from the north corner to the south corner. Another depression of about the same depth apparently exists in the Seneca Superior mine under Cart lake. A corresponding promontory of similar height lies along the brow of Nipissing hill above the north end of the higher tailings dam.

A few other minor irregularities in this old land surface have been noted; but for all purposes significant to mining operations, the surface may be assumed to have been originally a nearly smooth flat surface folded only after the advent of the diabase.

Bastin,¹ in 1917, after making an examination of the Cobalt ores with the microscope, applies the theory of enrichment by descending surface solutions to account for the rich silver ores of Cobalt.

¹Significant [Mineralogical] Relations of the Silver Ores of Cobalt, by Edson S. Bastin, Econ. Geol., April-May, 1917.

Collins,¹ in 1917, finds that the Huronian in the Onaping and Gowganda areas consists of a single series—the Cobalt series. It is composed of conglomerate, greywacké, quartzite, and one thin formation of siliceous limestone. It is separable into two quite distinct parts. The lower part is made up dominantly of dark grey conglomerates and greywackés regarded as probably of glacial origin. For this lower part he suggests the name Gowganda formation, as the rocks are exceptionally well developed in the Gowganda area. The upper part of the series is thick and consists of quartzite, the lower part of which is called the Lorrain quartzite.

In spite of their diversity of appearance, composition, and genesis, these two parts of the Cobalt series are largely in conformable relation to each other. An unconformity exists in a few places.

Reid,² in 1918, reviews Bastin's paper³ in which Bastin regards the silver ores of Cobalt as secondary in origin.

Reid believes that the theory of secondary enrichment is inapplicable to the Cobalt deposits, owing to the slight apparent relation of the ore-shoots to the surface as indicated by the absence of the zones of oxidation and of primary ore or protore—two of the most important criteria for the recognition of secondary deposits. The silver veins in their origin are related primarily to the diabase intrusion, and secondarily to various structural conditions in its neighbourhood, to wit, areas of local differential fracturing around the borders of the intrusive body, probably caused by compressive stresses. This fracturing, and especially the attendant mineralization, is local in character and does not extend beyond the contact area; it is due to the relative frangibility and permeability of the rocks involved. In this relationship the conglomerate takes the first place, diabase the second, and Keewatin the third. The enriching solutions are considered to be deep seated in origin, being connected with the diabase magma and consequently alkaline in reaction, the silver being probably carried in carbonate solution.⁴

Whitehead,⁵ in 1920, comes to the conclusion that the Cobalt series is of normal stream origin. Striated pebbles, which have been mentioned as an indication of the glacial origin of these strata, were found during the investigation, but are believed to have been crushed by the dynamic deformation of the rocks. The parts of the basal conglomerate resembling residual soil and breccia, the well-sorted character of many beds, and the usual stratification, unite to offer proof of fluvialite origin.

Faults.—The faults of the area are all reverse faults. The familiar dip-slip fault is the usual form, but displacement is often principally lateral.

By far the greatest number of ore-shoots in the district are determined, however, by flat-dipping shear zones or faults. Such faults lie in many places in a zone of movement upon and near the Huronian-Keewatin contact. Similar planes of movement, deflected from this contact by irregularities, primary or due to folding or faulting, lie partly in the Huronian sediments, or, where formed with no relation in the contact, lie wholly in these sediments. Other contacts, as those of the diabase and Keewatin, and of the diabase and Huronian, are loci of similar movement, and such shear zones may lie also within the diabase. Where faults are distributive on the bedding of slates, great masses of low-grade

¹ Onaping Map Area, by W. H. Collins, Geol. Surv. Can., Memoir No. 95, 1917.

² J. A. Reid, Econ. Geol., July, 1918.

³ Significant Mineralogical Relations of the Silver Ores of Cobalt, by Edson S. Bastin, Econ. Geol., April-May, 1917.

⁴ This summary was especially written by Mr. Reid for this report.

⁵ The Veins of Cobalt, Ontario, by W. L. Whitehead, Econ. Geol., Vol. 16, No. 2, March, 1920.

ore have been formed near veins. Above the contact or near a fault plane, which is usually heavily mineralized by calcite, fan-shaped ore-shoots lie in the vein and possess typical peripheral mineral variations. Nearest the fault the vein contains predominantly smaltite, often with dull silver-gray cores of a mineral, probably cobaltite. Away from the ore-centre, niccolite cores in smaltite spherules are encountered, and transition takes place in turn between these spherules into massive niccolite. At the periphery sparsely disseminated niccolite or smaltite spherules pass into pure calcite of pinkish colour. Silver content decreases gradually but surely from the central axis, near the fault, to the periphery of the shoot.

Such ore-shoots have been developed in their lower portions 1,000 feet or more laterally, and have extended from 250 to 300 feet vertically. Many do not outcrop; indeed their upper portions are often 300 feet or more below the surface, and smaltite with native silver has been found 1,600 feet in depth at the Beaver mine.

He reaches the conclusion that downward secondary enrichment has been essentially absent as a factor in the deposition in the Cobalt ores and that silver of the veins is due to the last stage of the primary mineralization.

He gives the following summary of his work:—

GEOLOGY

1. The Cobalt series is of stream origin.
2. Its base was a topography of slight relief.

STRUCTURE

1. The rocks of the district were subjected to deformation by forces of compression upon two normal axes.
2. The structures developed are essentially contemporaneous.
3. The major fractures of economic importance were formed in definite relation to faults and folds.
4. These fractures were probably due to local tensional stress.

VEINS

1. The veins are but slightly faulted, and are about of the same age.
2. They may be classified by
 - (a) Attitude,
 - (b) Certain structures determining ore-shoots.
3. The mineral content is influenced by the type of joint on which the vein was formed.
4. The veins are predominantly due to replacement.
5. During an early hypogene stage calcite, dolomite, arsenides and sulphides were deposited.
6. During a late hypogene stage silver was deposited.
7. Supergene silver deposition is essentially absent from the veins.
8. The veins were probably formed by hot waters, of deep seated, possibly magmatic, origin.

Burrows,¹ in 1920, publishes his third report on Gowganda, the two previous reports forming part of Miller's report on Cobalt. The third report deals mainly with recent developments in Gowganda, particularly in the vicinity of Miller lake. He finds the rocks in general similar to those at Cobalt.

Hume,² in 1920, describes the Paleozoic rocks north of Lake Timiskaming and gives an account of the Lake Timiskaming fault. His views regarding the fault are summed up in Chapter I.

Whitman,³ in 1920, comes to the conclusion that:—

1. The cobalt-nickel-silver ores of the Cobalt district were derived by diffusion and metasomatic fixation from the sill of Nipissing diabase with which they are associated.
2. They were deposited essentially in their present form below the groundwater level, not by circulating solutions, but by migrant ions traversing virtually stagnant or slowly circulating aqueous solutions, from all parts of the adjacent diabase, to such favourable seats of deposition as were accessible in the neighbourhood of its margins.

¹ Gowganda Silver Area, by A. G. Burrows, Ont. Dept. Mines, Vol. XXIX, pt. III, 1920, pp. 77-88.

² Am. Jour. Sci., 4th ser., Vol. 50, 1920, pp. 293-309.

³ Diffusion in Vein-Genesis at Cobalt, by Alfred R. Whitman, Econ. Geol., Vol. 15, No. 2, March, 1920.

3. Mineral-laden water filled all the pores, joints, and fractures of the diabase and its neighbouring rocks; and through it moved the ions of vein material, at a temperature considerably below the melting point of the diabase, and at a pressure of several thousand feet of hydrostatic head. These ions were not capable of combination and precipitation without the help of an external agency; this consisted in catalytic influences or obscure metasomatic reactions of a kind which could take place only in rock relatively free from stress in one direction, as that must have been, which lined the sides of vertical tension joints lying parallel with the chief lateral stresses of the locality. The effect of these reactions of replacement, although virtually grain-for-grain as is understood by the term *metasomatic*, was to send into solution the aluminous and ferrous silicates composing the wall rocks, and to fill the vacated space grain-for-grain as it developed, with the ore minerals. The first rock to be thus replaced was that under least stress on the immediate walls of the indicated joints. The joints being tight, there was virtually no opportunity for crustification. The replacement extended outward from the plane of its inception, the widening vein always being so firmly frozen to its walls that aqueous solutions would move along it often with less ease than elsewhere through the wall rock.

Miller and Knight,¹ in 1920, propose to employ the name Haileyburian for intrusive dikes and other masses of lamprophyre and peridotite which are post-Timiskaming and pre-Algoman in age. The name is taken from that of the capital of the District of Timiskaming, the town of Haileybury. The following table shows the position of the Haileyburian rocks:—

PRE-CAMBRIAN EPOCHS OF ONTARIO AND THEIR METAL PRODUCTION

(*Keweenawan*).—Epoch, following basic intrusions, of (a) silver, cobalt, nickel, and arsenic at Cobalt and elsewhere; (b) nickel and copper at Sudbury, and copper elsewhere. Certain gold deposits, not now productive, appear to belong to this epoch.

(*Animikean*).—Epoch of deposition of "iron formation" as a chemical precipitate. Includes the Cobalt and other series of sediments.

(*Algoman*).—Epoch, following granite intrusions, of gold at Porcupine and at many other localities, and of auriferous mispickel. Deposits of galena, zinc blende, fluorite, and other minerals appear also to have been derived from the granites, but some of them were not formed till post pre-Cambrian time.

(*Haileyburian*).—Preceding the intrusion of the Algoman granites, basic intrusives, of post-Timiskaming age, gave rise to nickel and titaniferous and non-titaniferous magnetite deposits and chromite.

(*Timiskamian*).—Epoch of minor deposition of "iron formation" as a chemical precipitate, with conglomerate and other sediments.

(*Laurentian*).—Granite intrusions probably gave rise to ore deposits which have been removed by excessive erosion as is known to be the case with deposits of later origin.

(*Loganian*).— { *Grenville*.—Epoch of deposition of extensive "iron formation" as a chemical precipitate, with limestone and other sediments.
(*Keewatin*).—Composed largely of basic lava flows, many of which are now schistose. There are also acid lava flows such as rhyolite.

Walker,² in 1921, thinks it probable that the material commonly called dyscrasite in Cobalt is made up of a eutectic intergrowth of silver and an antimonide of silver, probably Ag_3Sb , which should contain 27.1 per cent. of antimony.

Bell,³ in 1922, describes the geology and silver deposits of South Lorrain with special remarks about the Keeley mine. He has the following remarks to make regarding the oxidation of Wood's vein:—

While most of the veins which have been prospected on the Keeley mines property show only superficial oxidation, Nos. 1 and 2 veins in the northern part of the property are slightly oxidized to a depth of 120 feet, and the southern portion of Wood's vein shows intense oxidation to the greatest depth yet attained (420 feet), a condition, as far as is known unique in the Cobalt district. The northern limit of oxidation on Wood's vein, which is quite abruptly demarcated, pitches steeply northward to about 350 feet, and from that depth to the deepest horizon of the

¹ Haileyburian Intrusive Rocks, by Willet G. Miller and Cyril W. Knight, Ont. Dept. Mines, Vol. XXIX, pt. I, 1920, pp. 235-236; Can. Min. Jour., Aug. 13, 1920.

² Dyscrasite from Cobalt, Ont., by T. L. Walker, University of Toronto Studies, Geological Series No. 12, pp. 20-22.

³ The Occurrence of Silver Ores in South Lorrain, by J. Mackintosh Bell, Bull. Inst. Min. and Met., Feb., 1922.

mine (420 feet) deeply southward. Not only is Wood's vein itself oxidized, but the oxidation extends into the footwall for an unknown distance, and the branching stringers on the hanging-wall connecting the parent vein with No. 6 show a similar change. It is obvious that such extensive oxidation, even along so strong a line of fracturing, cannot be post-glacial, but must have ante-dated the glacial epoch. The greater depth to which oxidation extends in the southern than in the northern part of Wood's vein is probably to be connected with the influence on the parent vein and its numerous branches of the position of the water-level in a pre-glacial topography, the nature of which is not now clear. It seems possible that glacial denudation was not as great in South Lorrain generally as at Cobalt, and that in the southern and particularly narrow part of the depression occupied by Wood's vein protection against corrosion was given by the walls of greenstone on either side, especially after the depression had been filled by debris with the initial advance of the ice.

(1) Generally speaking, the richest and most persistent ore-shoots occur at or near the diabase-Keewatin contact, either within the diabase or within the Keewatin; the immediate contact is commonly barren or of low grade.

(2) An ore-shoot in the Keewatin does not ordinarily persist down into the diabase; or, vice versa, one in the diabase extend upward into the Keewatin. In other words, one part of a vein may carry ore in diabase, another in Keewatin.

(3) Gently inclined fractures, parallel to the contact and transverse to the dip of the veins, have an enriching effect upon the vein material.

(4) The junction of one vein with another, even a considerable distance from the contact, affects the values either in one vein or the other, or in both. If the veins are valueless before joining, a shoot of greater or less length is commonly made in the united vein.

(5) The values of a vein within sufficient distance of the contact, even in the smaller veins, are likely to improve when the vein occurs in a well-fractured zone, with cracking developed parallel to its strike.

(6) Ore-shoots are frequently localized on a main vein between the points of departure of two minor branching veins, or between the points of crossing of two zones of fracturing.

(7) When the ore-shoots are in Keewatin rocks, the most favourable type is an extremely dense fissile well-fractured greenstone. Lamprophyre is generally much less favourable, though some of the richest ore is found in fault planes when greenstone occupies one wall and lamprophyre the other.

(8) Generally speaking, the veins are more likely to carry ore when the dip of the vein is steep (upwards of 70 degrees) than when it is flat. Wood's vein, however, carries large amounts of ore when the dip is as low as 60 degrees, or even less.

The oxidized zone in Wood's vein reaches its northern-most extension in the mine workings at a depth of about 350 feet. On the surface, the outcrop of the vein occupies, as previously indicated, a relatively deep depression filled with boulder clay, and the vein has been exposed northward of the portion so heavily oxidized below ground. Whether oxidized material actually now occurs in this northern part of the vein or not, seems unimportant as compared with the certainty that it was oxidized in harmony with the vein farther south, though not to the same extent prior to glaciation.

The very rusty character of the veinstone, showing the presence of abundant iron in the ferric condition, indicates its derivation from pyrite or some iron-bearing sulphide, such as chalcopyrite, both of which are common in the unoxidized portions of the vein.

It is easy to understand how acidic ferric sulphate solutions, carrying their burden of silver leached from Wood's vein, seeped down its broad crushed zone into transverse veins below the hanging-wall (such as No. 16), where under changed chemical conditions the native silver was redeposited, and, on similar reasoning, how the ore-shoots of the northern upper unoxidized portions of Wood's vein were enriched by silver derived from the leaching of still higher sections of the vein, much of which may long since have been removed by erosion.

The fact that the southern oxidized portion of Wood's vein carries considerable silver ore from the surface downward to about 250 feet and is barren, or at least very low-grade, below that depth to the lowest horizon reached (420 feet), is explained by the super-saturation of solutions with oxygen, though the oxidation of all available sulphides near the surface, and the consequent necessity of reprecipitation of at least a certain portion of the silver dissolved, in accordance with the required state of chemical equilibrium. The relatively large amount of silver in the upper oxidized portion of Wood's vein has been derived from the eroded parts of the vein, and the enriched "gossan" has migrated downward with the progress of weathering, following the recognized rules of surface enrichment, except inasmuch as there was drastic erosion during glacial times. The barrenness of the oxidized zone in depth follows logically the assumption that at these inferior horizons there was originally sufficient sulphide present to satisfy the requirements of such oxygen as penetrated with surface waters to those depths, and that thus an acidic sulphate solution was again produced to carry the silver downward, leaving behind vein-material practically leached of all its values. It is noteworthy to mention that the silver in the oxidized surface-enriched ore is mainly in the native form, while that in what is considered to be largely secondarily-enriched ore below the oxidized zone is chiefly argentite, ruby silver, and stromeyerite, with less conspicuous native silver, generally in the wire form. In this secondarily-enriched ore, marcasite is invariably present and is especially conspicuous in the typical example of enrichment in No. 16 vein (420 feet).

The writer's opinion, it may be said in conclusion, is that while the primary silver-bearing material, including much of the high-grade ore, either in all of the veins near the diabase-Keewatin

contact, or relatively remote therefrom, in Wood's vein, where structural conditions determining its deposition were present, is due to hypogene agencies, there has been widespread enrichment by descending solutions, which has materially changed the primary mineralization.

Bell,¹ in 1922, reviews the early history of South Lorrain, and gives a summary of the geology.

Knight,² in 1922, gives a brief account of the work, carried on in 1920 and 1921, during a geological survey of the underground workings of Cobalt and South Lorrain:—

In making the resurvey, the broad general principles of structure which were worked out by Miller in the early days of the camp were found to be correct; but extensive mining operations, carried on since Miller's last report was published, have revealed certain structures of great economic importance. These structures and their relationships to ore-shoots could not be recognized and understood until mining operations had advanced beyond the stage reached at the time Miller's last report was issued.

One of the most important structures regarding the ore-bodies is the general occurrence of the silver ore-shoots at and near contacts. The mine operators have found, for instance, that the silver occurs largely at and near the base of the Cobalt series, along the contact with the underlying Keewatin rocks. It has been shown that the silver ore-shoots seldom rise more than 150 or 200 feet above this contact, although the veins themselves, consisting mainly of calcite, do rise in many instances higher than this.

Mining operations in recent years have gradually demonstrated that certain faults appear to limit, to some extent at any rate, the area in which productive veins occur. These faults are older than the ore-bodies. The outstanding example of such a fault occurs at the northern end of the Cobalt camp. This fault, which is a normal one with a displacement of from 4 to about 25 feet, strikes east 22 degrees south and dips to the southwest 70 to 90 degrees. It is a remarkable fact that north of the fault in the Cobalt area proper practically no high-grade ore has been found and only about 200,000 ounces of milling ore has been discovered. The fault itself contained important quantities of high-grade silver ore, both in the Hudson Bay and Nipissing mines; in the latter the vein was 26 inches wide in places.

He suggests that such faults as this have acted as dams, or impermeable barriers, through which, on account of the clay gouge in the fault, the solutions carrying the silver were not able to penetrate to any important extent.

Whitman,³ in 1922, concludes that:—

The fissures in which the ores were deposited were not cooling cracks in the strict sense, but were joints developed as a result of folding subsequent to the solidification of the diabase, and that the ores were derived from the diabase sheet itself, transported, and deposited chiefly through the agency of diffusion through relatively stagnant water in the pore spaces of the rocks.

The folds, which affect diabase and sediments alike, are parallel with the major structural axes of the region and also with the original undulations of the diabase sheet which transgress the sedimentary beds, these folds being indicated in the diabase by innumerable large and small surfaces of shearing parallel with the surface of folding. The vein joints are spatially related to the folds and to the faults which originated during the folding. From these relationships it is inferred that such joints are genetically related to the other deformations, and to external compressive stresses rather than to direct cooling shrinkage. It is immaterial, and impossible to conjecture, whether this compressive stress arose chiefly from the lateral expansive force due to the heating of the locality of the sheet, or whether it arose chiefly from the general contraction due to the cooling of the locality of the sheet, the latter having an undulating configuration, and the undulations being weak to lateral compression resulting from the contraction of their general environment. Since all the deformations, however, are clearly of the same immediate period as those in the diabase, the conclusion seems inevitable that the diastrophic activity followed the solidification of the igneous mass, and was of a compressive character.

In connection with the genesis of the ores it was pointed out that the commercial veins of the whole region as well as those in other parts of northern Ontario lie exclusively within marginal zones of the Nipissing diabase extending not more than 350 feet inward and outward in the diabase and Keewatin formations, nor more than 550 feet from the diabase margins in the Cobalt series of sediments. Even the noncommercial deposits and traces of cobalt in the northern part of the province are clearly related to the diabase, and no occurrences are known in this whole region that are clearly related to deep fissures in controversy of this rule. These facts are taken as strong evidence that the visible diabase itself was the source of the ores.

¹ Discussion on the Occurrence of Silver Ores in South Lorrain, Ont., Can., by J. Mackintosh Bell, E. T. McCarthy, H. F. Collins, J. A. L. Henderson, and R. T. Hancock; Bulletin 8, Inst. Min. and Met., Mar., 1922, pp. 1-14.

² Cobalt—Its Past and Future, by Cyril W. Knight, Eng. Min. Jour., May 6, 1922.

³ Genesis of the Ores of the Cobalt District, Ont., Can., by Alfred R. Whitman, University of California Publications, May 31, 1922.

Negation was resorted to in order to exclude any supposition that the ores might have originated either through the downward circulation of vadose waters or through the upward circulation of juvenile or of hot meteoric waters. These matters need not, perhaps, be reviewed here further than to recall that the principal points made in regard to ascending solutions were: (1) that the heated mineral waters of the earth, whatever their origin, are known to be very dilute, so that large volumes would be required to pass through the rock in order to produce a moderate amount of metasomatic ore; (2) that in the absence of crustification and comb structure, metasomatic veins can be supposed to have grown only by marginal accretion; (3) that the chief circulation of underground water must be through fissures, and that its passage in volume through pore spaces must be practically inhibited by the large coefficient of friction due to the narrowness of the capillary and subcapillary openings and the tortuousness of its course; and (4) that, at least in the case of the silver ores under discussion, the veins and vein walls offer no more porous courses for the passage of water than the country rock offers, and therefore there would be no directive agency to cause mineral-bearing solutions to circulate there rather than at random through the country rock.

At Cobalt the chief ore production has come from beneath the diabase sheet, the veins being metasomatic replacements of the walls of *cul de sac* fractures. It seems far-fetched to suppose, since the diabase invaded chloritic schists which must have been saturated with ground water, that mineral-bearing solutions could have circulated downward from the diabase into the already saturated country rock in sufficient quantity and strength to have produced such metasomatic deposits in those blind fractures. Local convection currents could be supposed to have only gone round and round in a fracture of that sort without any chance of replenishing their original supply of mineral.

Water circulation being practically inhibited, recourse must be had to the principle of diffusion to explain the transference and deposition of mineral; but slow as would be the migration of metalliferous ions through the pore spaces of the rock, it would nevertheless be that of mineral at 100 per cent. concentration; and, furthermore, it would be directed from the point of its origin to the point of deposition by the steepening of the diffusion gradient at the point where precipitation is going on.

Time seems to be the chief obstacle in the way of accepting diffusion as a dominant agency in the genesis of metasomatic ore deposits. The ratio of its effectiveness to that of water circulation is the point in doubt. There are two forces which may be considered as tending to actuate the circulation of water through the pore spaces of rock, capillarity and hydrostatic head, or difference in head. Capillarity operates only in the first wetting of the rock; after that hydrostatic head is the sole actuator. In the depths this can arise only from heat or the compression of rocks containing water in sufficient quantity to be squeezed out. In either case the head would have to be considerable to drive water through capillary openings for a great distance; and the propagation of that force would be so slow that the passage of large volumes of water past a certain point within a firm rock might easily take as much time as the migration, by diffusion, of an equivalent amount of mineral ions. This ratio of effectiveness is at present indeterminable, and must await the results of experimentation. In the meantime, however, we have some very definite chemical facts in which to find assurance that diffusion is a factor to be reckoned with. Fick, Sorlet, and others have made it clear that when a solute is in contact with a solvent it tends to diffuse into the solvent until equally distributed through it. The diffusion gradient consequent upon Fick's law supplies a directive agency and a means of acceleration the moment precipitation begins within the field of diffusion. Its operation is slow but relentless. The force actuating the diffusion of salts has not been measured directly, but its supposed equivalent in osmotic pressure has been equated and measured, and found in certain instances to attain a magnitude of many atmospheres. Thus we already know that where there is water and a solute, the latter will tend to migrate through the former without cessation until equally dispersed through it; and when obstructed it will be assisted by the force of osmosis. Given the time, then, which is required for the flow of large volumes of water through a great thickness of firm rock, diffusion is a factor to be considered. The particular utility of that concept in assisting the understanding of the phenomena of vein genesis lies in the subtlety, mobility, efficiency, and vector quality of diffusion.

Knittel,¹ in 1922, finds small quantities of platinum and palladium in the anode slimes resulting from the electrolytic refining of silver recovered by smelting ores from the Cobalt district.

Watson,² in 1922, in a general review of the Cobalt silver area points out that the main Cobalt area is four miles long by two miles wide, and that in this area there were about thirty producing mines. Diligent exploration for years has failed to extend the limits of the main area, although the formation is favourable on three sides.

¹ Notes on the Detection and Estimation of Small Amounts of Platinum and Palladium in the Presence of Large Amounts of Silver, by G. A. Knittel, Can. Chem. and Met., Aug., 1922, p. 179.

² R. B. Watson, Financial Post, Toronto, Oct. 27, 1922.

The ores are found over a stretch of country from South Lorrain to Gowganda; this shows that the solutions depositing the ores came from different sources, or at least have been widely distributed from the same source. This leads to the hope that other occurrences will be found in the great area of favourable rocks in northern Ontario.

The most remarkable feature of the Cobalt camp from the investor's standpoint is the large per cent. of the money received from the sale of ore, which has been returned to the stockholders in dividends. The Nipissing, for instance, up to the end of 1921, had produced \$41,000,000 worth of ore, and had disbursed \$23,640,000 in dividends. Adding the cash and ore on hand brings this latter figure up to \$27,000,000. In other words, the stockholders have received in dividends 66 per cent. of all the money taken in.

He considers that it takes a long time for a good camp to die. On the older properties the favourable territory has been pretty well prospected; the easy ore has been found. There is a large area, however, which is overlain by the diabase sill; the contact of this sill with the underlying rocks offers possibilities for the adventurous. Prospecting for these contact ore bodies will be expensive on account of the lack of surface indications, and is not likely to be generally undertaken, except where the contact can be reached without great expense, or where the conditions indicate an ore-body at a certain place, such as at the Colonial where a vein on the adjoining property, the O'Brien, has been developed.

Knox,¹ in 1922, discusses an effect of climatic change on the superficial alteration of ore deposits, and cites as examples the Keeley mine in South Lorrain and the group of copper deposits at Soymanovsk near Kyshtim in the Urals.

Burrows and Hopkins,² in 1922, map and report on an area which lies to the north and northwest of Lake Timiskaming. They find the succession of rocks the same as that described by Miller in the Cobalt area. In Mulligan township, however, an area of mica schist was met with which they state resembles the Couchiching of Western Ontario. They also encountered a massive altered diabase which in their opinion may be pre-Algonian in age.

In Cane and Auld townships there are a number of veins of calcite and dikes of aplite containing silver. They occur toward the hanging-wall side, or upper part, of the diabase sill.

The gold deposits of Bryce township are described.

Parsons,³ in 1922, describes the hemimorphic character of a crystal of proustite from Cobalt.

Burrows,⁴ in 1922, finds that in Gowganda nearly all the silver occurs in the Nipissing diabase at the top of the sill. In addition to those veins found in the diabase, a few silver-bearing veins have been discovered in the Keewatin greenstone, and the conglomerate of the Cobalt series. Where the discoveries in the Keewatin and diabase have been made, these formations overlie the diabase sill and the veins are near the hanging-wall contact. At the Millerett mine (Miller Lake-O'Brien) 500,000 ounces of silver were produced from conglomerate of the Cobalt series above the Nipissing diabase sill. In Gowganda no silver-bearing veins have as yet been found in rocks that lie below the diabase sill.

¹ An Effect of Climatic Change on the Superficial Alteration of Ore Deposits, by Henry H. Knox, *Econ. Geol.*, Vol. XVII, No. 8, Dec., 1922.

² Blanche River Area, by A. G. Burrows and P. E. Hopkins, *Ont. Dept. Mines*, Vol. XXXI, pt. III, 1922.

³ A Third Type of Proustite from Cobalt, Ont., by A. L. Parsons, *University of Toronto Studies, Geological Series No. 14*.

⁴ Gowganda Silver Area, by A. G. Burrows, 4th ed., *Ont. Dept. Mines*, Vol. XXX, pt. III, pp. 1-54.

He classifies the rocks as follows:—

POST-KEWEENAWAN.....Olivine-diabase, quartz-diabase aplite.

KEWEENAWAN.....Quartz-diabase (sill).

Intrusive contact

ANIMIKEAN (Cobalt Series).....{ Upper: Conglomerate, quartzite, arkose.
Lower: Conglomerate, greywacké, quartzite.

Unconformity

LAURENTIAN(?).....Granite, syenite, gneiss.

Intrusive contact

KEEWATIN.....Basic and acidic volcanic and intrusive rocks, iron formation, chlorite and hornblende schist, etc.

Bastin,¹ in 1922, makes a study of the native-silver ores near Wickenburg, Arizona, and compares them with the silver ores at Cobalt. His conclusions are as follows:—

1. The ores of the Monte Cristo mine, near Wickenburg, Ariz., occur as replacement veins in rocks of probable pre-Cambrian age. There is no direct evidence of the age of the mineralization. If, as seems likely, these veins were formed contemporaneously with most other ore deposits of this region, their age is probably late Tertiary.

2. The minerals listed below were noted in the Monte Cristo ores; the commoner ones are shown in italics.

Primary (hypogene): *Chalcopyrite*, *pyrite*, *arsenopyrite*, sphalerite, galena, *tennantite*, enargite, specular hematite, *quartz*, *barite*, magnetite, *niccolite*, *chloanthile*, gersdorffite, *native silver*, proustite, pearceite, argentite, *calcite*, and *siderite*.

Secondary (supergene): Argentite (?), erythrite (cobalt bloom), annabergite (nickel bloom), and limonite.

3. Although several ore types are recognizable there is no clear evidence of more than one general period of primary mineralization.

4. The microscopic relations in the Monte Cristo ores show clearly that the silver-bearing minerals—native silver, proustite, and pearceite—are primary (hypogene), having crystallized contemporaneously with several of the commoner and unquestionably primary ore minerals. These three silver minerals never replace other minerals in these ores.

5. In some of the Monte Cristo ores argentite has replaced native silver. This argentite is clearly contemporaneous with calcite and is believed to be late primary (hypogene) rather than secondary (supergene).

6. Downward enrichment in silver is negligible unless some argentite is to be interpreted as secondary (supergene). Downward enrichment in copper is limited to the formation of peacock tarnishes on chalcopyrite.

7. Waters dripping through the vein are neutral.

8. Oxidation has been slight.

9. The undoubted primary association of native silver with nickel arsenides in the Monte Cristo mine lends credence to the view that the native silver associated with cobalt and nickel arsenides and antimonides at Cobalt, Ontario, and elsewhere may also be mainly primary.

10. The native silver at Cobalt differs from that at the Monte Cristo mine in that it is not contemporaneously intergrown with the cobalt and nickel arsenides and antimonides but has replaced them. For this reason it has been thought by some to be a product of downward enrichment through the agency of solutions carrying silver in balance with the sulphate radicle. The field relations at Cobalt indicate, however, that the rich silver ores are primary and offer apparently insuperable obstacles to the hypothesis of downward enrichment.

11. The abundance of carbonates and the absence of sulphates in the Cobalt ores suggest that in the mineralizing solutions silver was carried in balance with the bicarbonate rather than the sulphate radicle.

12. A restudy of typical Cobalt ores showing that silver and calcite have simultaneously replaced niccolite also suggests that silver deposition was accomplished by carbonate rather than sulphate solutions.

13. Qualitative experiments prove conclusively that cobalt and nickel arsenides and antimonides are effective precipitants of metallic silver from silver bicarbonate solutions, nickel and cobalt being simultaneously taken into solution. The reactions are analogous to those previously worked out quantitatively for silver sulphate solutions, except that the solutions remain neutral after the reactions.

14. The field relations of the Cobalt deposits, the microscopic relations of the silver to the other ore minerals, experimental work with silver bicarbonate solutions, and partial analogy with the Monte Cristo ores all appear to favour the hypothesis that the rich native silver ores of the Cobalt district are late primary (hypogene) deposits from bicarbonate solutions.

¹ Primary Native Silver Ores near Wickenburg, Arizona, by Edson S. Bastin, Bull. 735E, U.S.G.S., 1922.

Sir Edmund Walker,¹ in 1922, in his presidential address to the shareholders of the Canadian Bank of Commerce remarks that for three-quarters of a century our geologists and other Canadians of reasonable intelligence have known that we possess in the centre of Canada the largest area in the world of the oldest rocks and of rocks immediately following these, all roughly classed as pre-Cambrian. These are most promising areas for the prospector. But we also possess in the Maritime Provinces and eastern Quebec our share of the Appalachian mountains, and in the far west our share of the vast Cordilleran areas. Of gold, silver, nickel, copper, asbestos, and other metals we are already important producers. We have iron ores in plenty, but these are not so readily available as the ores mined in that comparatively small extension of our pre-Cambrian area into the United States, which is so wonderfully rich in iron and copper as to be famous throughout the world. What we have accomplished thus far in the three great mining areas has been largely the result of accident; we can hardly pretend that there has been serious prospecting in many of the mining fields of Canada, except by a very small number of trained experts.

Collins,² in 1922, publishes a geological map of northern Ontario. This map includes Cobalt, Porcupine, Kirkland Lake, and Sudbury, and the country as far west as Lake Superior. It also embraces a narrow fringe of western Quebec. The legend published with the map appears below.

LEGEND

(After W. H. Collins)

PALEOZOIC QUATERNARY		Glacial drift and post-Glacial lake beds
	SILURIAN AND ORDOVICIAN	Limestone, shale and sandstone
HURONIAN	KEWEENAWAN	Killarney granite and gneiss Quartz diabase and quartz norite intrusives The Thessalon greenstone and later olivine-diabase dykes are included in this group, although not of exactly the same age.
	WHITEWATER SERIES	Conglomerate and sandstone Trout Lake conglomerate, Onaping tuffs, Onwatin slate and Chelmsford sandstone
	COBALT SERIES	Lorrain quartzite, banded cherty quartzite and upper white quartzite Gowganda formation (conglomerate, greywacké, quartzite and limestone)
	BRUCE SERIES	Serpent quartzite Bruce conglomerate, Bruce limestone, Espanola greywacké and Espanola limestone Mississagi quartzite Granite-gneiss and related acid plutonic rocks
PRE-HURONIAN	BATHOLITHIC INTRUSIVES	Gneiss A complex association of igneous granite and granite gneiss with highly metamorphosed sedimentary materials (stratiform gneisses, quartzites and crystalline limestone) of Grenville-like appearance. Hitherto believed contemporaneous with gneiss above, or older, but the igneous members are now known to be in part, if not altogether, of the same age as the Killarney granite.
	SEDIMENTS	Doré series, Sudbury series, Timiskaming series, Pontiac series These sedimentary series, though grouped together as pre-Huronian sediments are not known to be of the same age.
	VOLCANIC COMPLEX	Iron formation (differentiated in places from the schist complex.) A schist complex essentially of volcanic origin; but containing some obscure sediments of pyroclastic origin and undifferentiated areas of iron formation.

¹ Presidential Address to the Shareholders of the Canadian Bank of Commerce, 1922, by Sir Edmund Walker.

² Map No. 155A, Portions of the District of Algoma, Sudbury and Timiskaming, Canadian Geol. Survey.

Miller,¹ in 1923, writes as follows:—

In northeastern Ontario, as is well known, the pre-Cambrian consists of a great variety of both igneous and sedimentary rocks that represent a vast period of time. In this region are also to be found some of the world's greatest gold, silver and nickel deposits. The age and structural relations of the rocks have been closely studied during recent years chiefly owing to their bearing on economic problems, and it has been found that owing to the variety of ore occurrences it is necessary to have a more detailed knowledge of the rocks than is required in most regions if prospecting and mining problems are to be satisfactorily solved. There is need of a knowledge of what rocks are genetically or structurally connected with certain ores and those that are not. For example, an older series of sediments, the Timiskaming, is found to be structurally related, at least, with the occurrence of gold deposits that are now productive, and certain acid rocks are genetically related to the same deposits. On the other hand, a newer series of sediments, the Cobalt series, is younger than the gold deposits, but in it has been found a high percentage of the silver ores. The silver deposits are genetically connected with certain diabases, the Nipissing series, that occupies large areas in the region.

It is difficult to distinguish certain igneous rocks from others that may be either younger or older, unless they are found in contact with rocks whose ages are known. The same may be said of certain sedimentary rocks of the region. But for economic reasons it is necessary to determine if possible the age relations. Prospectors, for instance, have spent time in searching for silver deposits in diabases that they mistook for the Nipissing diabase but which were really of much greater age. Similarly, older porphyries have been mistaken for the newer, that are associated with gold deposits.

A good example of a series of older diabases that have in one or two areas, at least, been mistaken for the newer Nipissing diabase is recorded by Mr. A. G. Burrows in his reports on the Matachewan and Gowganda areas.

Similar observations have been made by Dr. H. C. Cooke on the occurrence of diabase dikes in the Matachewan area. D. G. H. Wright has also found the same series of dikes in the Watabeag area. Miller has named these diabases the Matachewan series.

Miller shows in the following table the relative position of the Matachewan series:—

EOZOIC OR PRE-CAMBRIAN

Upper	{ (Keweenaw)—Nipissing diabase, etc., of N.E. Ontario. Animikean—sediments of Cobalt series, etc.
	<i>Great Unconformity</i>
Middle	{ (Matachewan)—diabase dikes, etc. (Algoman)—granite, porphyry, etc. (Haileyburian)—lamprophyre, diabase, etc. Timiskamian—sediments.
	<i>Great Unconformity</i>
Lower	{ (Laurentian)—granite, etc. { (Grenville)—limestones, etc. { (Keewatin)—basic lavas, etc.

Miller,² in 1923, constructs a diagram which shows the triangular relations of Sudbury, Cobalt, and Porcupine.

Knight,³ in 1923, reports on the South Lorrain silver area. His report forms Chapter III of the present report.

Walker,⁴ in 1923, describes a coarsely porphyritic dike of diabase from Gowganda. The diabase is fine-grained and shows typical ophitic structure. The augite is fairly fresh, though the plagioclase is so strongly altered that only on the outer zone of an occasional crystal can the characteristic twinning be

¹ The Matachewan Series and its pre-Cambrian Relations, by Willet G. Miller, Can. Min. Jour., April 20, 1923.

² Ontario's Triumvirate of Great Mining Areas—A Remarkable Triangle, by Willet G. Miller, Can. Min. Jour., June 22, 1923.

³ The South Lorrain Silver Area, by Cyril W. Knight, Ont. Dept. Mines, Bulletin No. 48, 1923.

⁴ Huronite from Gowganda, Ont., by T. L. Walker, University of Toronto Studies, Geological Series No. 16, 1923.

observed. The porphyritic crystals are somewhat rounded, are pale yellowish-green, and attain a diameter of one and a half inches. An analysis of the phenocrysts gave the following results:—

	per cent.
SiO ₂	46.98
Al ₂ O ₃	30.18
Fe ₂ O ₃	.95
FeO.....	.42
CaO.....	9.38
MgO.....	.39
MnO.....	.04
Na ₂ O.....	1.36
K ₂ O.....	6.40
H ₂ O.....	4.05
CO ₂	.27
	100.42

Walker believes this material to be scapolite, a mineral into which basic plagioclase frequently alters. In thin sections under the microscope the phenocrysts are seen to be composed of an exceedingly fine-grained aggregate, which is somewhat fibrous in texture.

Miller,¹ in 1923, describes the geology and ore deposits of the Cobalt area. This is a reprint of the Guide Book prepared for the International Geological Congress in 1913.

Bastin,² in 1923, during the month of August, writes as follows:—

The veins of the Frontier mine (South Lorrain) follow steeply inclined zones of fracturing of general northerly and southerly trend. The ore has been deposited in part as a filling in open cracks as in the Watson vein, third level, where open cavities lined with successive layers of ore minerals are common. In the main, however, the work has shown that most of the ore has been deposited by the process known as replacement. Where the veins now are there existed prior to mineralization zones where the rocks were traversed by numerous nearly parallel fractures or where they had been crushed to an aggregate of small fragments. Large open spaces were rare. Along these fractured and brecciated zones the mineralizing solutions circulated dissolving rock material and depositing ore minerals in its place. Even some of the veins that are sharp-walled have been formed in this way. The practical importance of recognizing replacement as the dominant method of mineralization lies in the fact that in the deposition of replacement veins variations in (a) kind of wall rock, (b) degree and manner of fracturing, and (c) extent of development of clay or gouge, exert a much larger control on mineralization than they do in the filling of open fissures. A small gouge-lined fracture may suffice to terminate abruptly an ore-body forming by replacement by acting as a barrier to the replacing solutions.

He finds that calcite, usually pink and iron-bearing, is the dominant gangue mineral. Quartz is also present.

The metallic minerals are:—

Arsenopyrite (FeAsS)	} Usually Dominant Metallics	Pyrite (FeS ₂)
Cobaltite (CoAsS)		Galena (PbS)
Löllingite (FeAs ₂)		Argentite (Ag ₂ S)
Niccolite (NiAs)		Proustite (ruby silver) (3Ag ₂ S. As ₂ S ₃)
Breithauptite (NiSb)		Sphalerite (ZnS) (Bismuthinite) (Bi ₂ S ₃)
Chalcopyrite (CuFeS ₂)		Native silver
Tetrahedrite (4Cu ₂ S. Sb ₂ S ₃)		Native bismuth

Although the gray metallics of the veins commonly go under the name of "smaltite" most of what has been termed "smaltite" is an intimate mixture of arsenopyrite and cobaltite with in places some löllingite. Further study may reveal some true smaltite.

All of the minerals listed above are unquestionably primary with the following exceptions:—

1. A small part of the silver.
2. Possibly some proustite.
3. Possibly some argentite.

¹ The Cobalt Area, by Willet G. Miller, Ont. Dept. Mines, Guide Book, Sudbury, Cobalt, South Lorrain, Kirkland Lake, Porcupine, and Timagami, 1923.

² The Frontier Mine, South Lorrain, by Edson S. Bastin, Special Report to the Shareholders of the Mining Corporation of Canada, Ltd., Sept. 17, 1923.

The study under the microscope of polished specimens of rich ore representative of all parts of the mine shows definitely that nearly all of the native silver of the mine is primary. Some of it is early primary and is contemporaneously intercrystallized with niccolite that was one of the first ore minerals to deposit. Most of the silver is, however, late primary and occurs together with calcite, tetrahedrite, chalcopyrite, sphalerite, and bismuthinite, in veinlet-like masses traversing the commoner metallic minerals and clearly the last portions of the ore to crystallize.

The evidence that most of the native silver is primary is definite and conclusive, and warrants the confidence that shoots of rich ore may be encountered to considerable depths unless other factors such as decrease in the degree of fracturing and of replacement with depth interfere.

In portions of the Wood's ore-shoot above the third level, argentite is abundant lining small vugs in very rich ore. This argentite interlocks intimately with undoubted primary minerals and seems itself to be primary. It was one of the last of the primary minerals to deposit. Further study may show that some argentite is a secondary deposit from descending solutions, but if present at all its quantity is unimportant from the commercial viewpoint.

Teeth and wires of native silver occur implanted in primary argentite in vugs in some of the ore of the rich Wood's stope. This silver is clearly an alteration product of the argentite. Ordinarily this alteration would be attributed to enrichment by waters descending from the surface, but in a few places the wires and teeth of silver have been partly reconverted to argentite—a change not characteristic of the action of descending surface waters. Further study may show that the formation of the silver wires and teeth had no connection with surface processes. At all events the silver values in the form of silver wires and teeth are small as contrasted with the more massive silver which is clearly primary, and the question of their primary or secondary origin is of minor practical importance.

Bell,¹ in 1923, describes the pre-glacial weathering of Wood's vein to a depth of 560 feet at the Keeley mine. He believes that some of the silver is secondary. His views are given more fully elsewhere in this report.

The Imperial Mineral Resources Bureau,² in 1923, gives an excellent review of the geology, production, and so forth of the Cobalt silver field. The report also deals with the silver fields of the British Empire and foreign countries for the period 1913 to 1919.

Spurr,³ in 1923, expresses the opinion that the veins at Cobalt are clearly intrusive veindikes, with perhaps some replacement of the wall rock on both sides of the veindike fissures. He considers that the veins have all the characteristics of true veindike fissures. They are branching and reuniting injections, enclosing isolated, sharp, angular fragments, and also long slabs of country rock. Successive substages or episodes of vein injection are shown, as in one specimen which shows an earlier injection of a smaltite (with much fine disseminated niccolite) veindike which was split along one wall, and a later injection of niccolite and calcite forced up. The occurrence of niccolite in both injections shows that these injections followed one another closely in point of time and constitute a phenomenon of fractional splitting, or magmation of the ore magma, which elsewhere in Cobalt frequently crystallized as a single veindike combining both these episodes; and that, therefore, these examples are hardly to be regarded as true compound veins, any more than are the veins at Porcupine or at Kirkland lake. The Cobalt veins are in the large sense one-stage veins exhibiting the usual differential crystallization, whereby some elements overlap and partially succeed others, where the crystallization was slow enough to allow this differentiation or magmation. Another instance of sequence of vein crystallization, which he observed in a specimen at the exhibit of Cobalt ores at the Nipissing mill, showed on the walls of a little veindike a first deposition

¹ Deep-Seated Oxidation and Secondary Enrichment at the Keeley Silver Mine, by J. Mackintosh Bell, *Econ. Geol.*, Vol. 18, No. 7, Oct.-Nov., 1923.

² The Mineral Industry of the British Empire and Foreign Countries. War period. Silver. Imperial Mineral Resources Bureau, 1923. Printed and published by His Majesty's Stationery Office, London, England.

³ The Nature of the Silver Veins at Cobalt, by J. E. Spurr, *Eng. and Min. Jour.-Press*, Oct. 27, 1923, pp. 709-712. The above is quoted practically word for word from Mr. Spurr's article.

of quartz, with a centre of arsenides (smaltite, etc.) and native silver. There was no second splitting here; the phenomenon was that of sequence of crystallization from an ore magma filling and distending a fissure which it had intruded—and cooling with sufficient slowness to permit in this unusual case a gradual crystallization.

The tendency of metals, in congealing ore magmas, to crystallize later than the bulk of the gangue minerals and also to segregate towards the walls (under gaseous tension pressure), or even to escape from the veindike into the walls or upwards into a just-crystallized portion of the veindike, to which tendency he has called attention as a rule of ore magma crystallization and has recently pointed out at Porcupine, is well illustrated at Cobalt, on a striking and important scale, by the occurrence of native silver, which characteristically partially escaped the veindikes, and occurs in crevices in a zone of country rock on either side, forming sheets and films of silver, and which, moreover, fills cracks and crevices in the earlier crystallized calcite-arsenide—native silver veindike, just as at Porcupine native gold does in the earlier crystallized quartz (gold) veindike. This silver-impregnated country rock, extending often several feet away from the veindikes (which themselves carry far more silver and constitute the phenomenally rich ore) makes up the considerable tonnage of low-grade or milling ore of the district. In the veindikes themselves, this late crystallization and high degree of mobility of the native silver has procured an irregular concentration of silver; so that, while some of the veins seen were reported to carry locally several thousand ounces of silver to the ton, similar veins and indeed other portions of the same vein, carry very little silver, while representing the same veindike intrusion, as shown by the presence of all the rest of the minerals of the characteristic veindike fabric, such as calcite, smaltite, and nicolite. The explanation for the high migrativeness and concentration of native silver above given, involves, of course, an upward as well as outward pressure in the veindikes: accordingly, the tops of veindikes (for some of the veindikes have been found to terminate upwards in the mines, constituting so-called “blind veins”) are said to be ordinarily relatively high in silver.

There is no question in his mind that the silver is a primary ore-magma mineral: not the result of alteration and concentration by surface waters, whose effect at Cobalt has been negligible. In Cobalt, indeed, there is practically no zone of oxidation and rearrangement by surface waters, the pre-glacial zone having been gouged away by the glacier, and subsequent (post-glacial) time proving to have been inadequate for much superficial decomposition. Knowledge of this type of ore deposit is recent, and when the rich native-silver ores were discovered and were later found to fail characteristically at a certain depth, geologists with knowledge of the formation of native-silver ores in the western United States, by reduction from sulphide ores under the influence of descending waters, were naturally inclined by analogy to regard the Cobalt ores as also secondary. But events and a better conception of the geology have proven that the analogy was a false one, and that the native-silver ore here is primary and truly magmatic.

The great influence of wall-rocks in determining the locus of precipitation of the net final fraction of the ore magma is as striking at Cobalt as at Porcupine, or even more so. At Porcupine, it will be recalled, a gold quartz veindike (for example in the McIntyre mine) which runs from the (basic) Keewatin schists into the siliceous porphyry, is apt to lose most of its gold values, though the veindike itself may proceed bravely on. And at Cobalt 80 per cent. of the ore has come from the conglomerates and other sediments of the Cobalt series,

into which series the diabase has intruded. Most of these exposed sediments at Cobalt underlie the diabase sill which has been partly stripped off by erosion; and veins pass downwards from the conglomerates into underlying Keewatin (basic) schists, representing ancient lava flows, essentially like those of corresponding age of Porcupine. Many of the veins lose much or practically all of their silver values when traced (downward) from the conglomerates into the Keewatin, while the vein itself (of smaltite, niccolite, calcite, etc.) sometimes proceeds on in full width. The controlling influence of the wall-rock on the precipitation of the final (silver) fraction of the ore magma is clear; and the explanation of this striking phenomenon is as nice a problem as it is in Porcupine—or even more exacting.

Considering first the chemical influence of wall-rocks on silver deposition, he has pointed out that the basic derived ore magmas, being calcic, would be most influenced to precipitation by siliceous wall-rocks, just as the siliceous-magma-derived ore magmas, being themselves siliceous, are best influenced to precipitation by basic wall-rocks. This would appear to be upheld at Cobalt, where the conglomerate and other sediments of the Cobalt series, containing a large amount of granitic material, should precipitate from calcic solutions more readily than should either Keewatin schists or the Keweenawan diabase, both basic rocks.

Bell,¹ in 1923, discusses the geology and ore deposits of South Lorrain. He says:—

The Nipissing diabase, in South Lorrain, occurs in the form of a wide sill that, after being folded into a broad dome, was subjected to pronounced faulting and long-continued erosion. To day, the centre of the formerly continuous dome is mainly a valley underlain by rocks of the Cobalt series and occupied by numerous small lakes, the largest of which are Loon and Oxbow. Along the outer slopes of the dome, Keewatin rocks are conspicuous; these, in turn, are generally overlain by rocks of the Cobalt series. Silver ores in appreciable quantity have been found in two localities only, namely along the western slope, where are situated the Keeley and the properties of the Mining Corporation, and along the northeastern slope, where the Canadian Lorrain silver mine is situated. The latter area is unimportant and, for the purpose of this paper, only the area adjacent to the Keeley and the properties of the Mining Corporation need be considered.

He considers that certain generalities govern the position of the ore-shoots in South Lorrain and Cobalt:—

(1) Generally speaking, the richest and most persistent ore-shoots occur at or near the diabase—Keewatin contact, either within the diabase or within the Keewatin; the immediate contact is commonly barren or of low grade.

(2) The junction of one vein with another, even a considerable distance from the contact, affects the values, either in one vein or the other, or in both. If the veins are valueless before joining, an ore-shoot of greater or less length is commonly made in the united vein.

(3) The values within a sufficient distance of the contact, even in the smaller veins, are likely to improve when the deposit occurs in a well-fractured zone, with cracking developed parallel to its strike.

(4) Ore-shoots are frequently localized on a main vein between the points of departure of two minor branching veins, or between the points of crossing of two zones of fracturing.

(5) When the ore-shoots are in Keewatin rocks, the most favourable rock is an extremely dense, fissile, well-fractured greenstone. Lamprophyre is generally less favourable, though some of the richest ore is found in fault planes where greenstone occupies one wall and lamprophyre the other.

(6) Generally speaking, the veins are more likely to carry ore where the dip of the vein is steep (upwards of 70°) than where it is flat. Wood's vein, however, carries large amounts of ore when the dip is as low as 60° or even less.

(7) It is noteworthy that where the dip of a vein varies from the vertical in both directions, one inclination may be productive and the other not.

The origin of the veins of South Lorrain, with their rich ore-shoots, is similar to that of Cobalt, where the question has received much attention from various authorities. The writer has given his opinions in this connection elsewhere and considers it unnecessary here to do more than

¹ South Lorrain Silver District, Ont., by J. Mackintosh Bell, *Trans. Am. Inst. Min. and Met. Eng.*, Jan. 1924.

repeat his conviction that while the greater part of the ore is primary and due to hypogene agencies, there has been, in places, material enrichment by descending solutions that derived their silver content from the now impoverished portions of the oxidized zones.

Bastin,¹ in 1923, considers the native silver at the Frontier mine, South Lorrain, to be primary.

APPENDIX²

In the following pages will be found an interesting account of the discovery and history of the Wright silver mine on the east shore of Lake Timiskaming. The Wright mine is one of the oldest in North America. This account of its discovery was published in *The Daily Nugget* in 1921, and in the Canadian Mining Journal. It was written by Mr. J. A. McRae.

In the National Library of Paris are some notes which deal with the discovery of lead ore in 1686 upon the eastern shore of what is now known as Lake Timiskaming. These notes were taken from the diary of Sieur de Troyes, and are referred to as "Relations and Journal of a journey to the North by a detachment of one hundred men under the command of 'Le sieur de Troyes,' in date of March, 1686."

Thus it was that at a time when a few venturesome souls, some of them perhaps with nothing short of an empire in their brains and some of them merely the *coureurs des bois* of a new continent, were engaged in the difficult task of establishing the white race in North America, an ore deposit was discovered, only to be lost, then found again after the sway of the Indian tribes had become dissipated before the advance of civilization in Canada.

NAMES OF OFFICERS OF THE DETACHMENT IN 1686

Chaplain—Rev. Father Silvie, Jesuite.

Commander—Sieur de Troyes.

Lieutenant—Sieur de St. Helene.

2nd Lieutenant—Sieur de Hyberville.

Major—Sieur de Maricourt.

Assistant Major—Sieur de La Noue.

Board Commissioner—Sieur Lallement.

(Also designed to command a vessel in case we should not locate one to come to Quebecq).

Captain of the Guides—Sieur de St. Germain.

NARROWLY MISSED ALTERING TIDE OF PROGRESS IN NORTH AMERICA

It is perhaps one of the strangest chapters in Canadian history that while attention has turned to the mineral possibilities of the country as far back as 1686, following this discovery on the eastern shore of Lake Timiskaming, yet within three miles of the western shore of the same body of water the fabulously rich silver veins of the Cobalt district actually lay bleaching in the sun until accidentally found in 1903.

Just here, it is interesting to indulge in conjecture as to what influence the discovery of these vast riches in native silver might have had upon early settlement on the North American continent. It seems quite safe to assume that had Cobalt been found in 1686, the attention of the Old World would have been focused with great intensity upon this region. It is not unreasonable to suppose that the tide of immigration to North America would have been in this particular direction. It is probable that bitter jealousies would have grown in the breasts of those who were blazing the western trails for France and those who were steering the destiny of Anglo-Saxon influence in the New World.

It is one of the marvels of the opening of Northern Canada that for more than two centuries white men, armed with all the inquisitive instinct of the race, should have trekked along Lake Timiskaming, camped upon its shores, and failed to receive any intimation from their fellows or from the natives of the rich silver veins lying in the very shadow of their camps.

But, to turn again to the history and romance of the Wright Mine: The following are notes as taken from the Commander's diary, dating from May 12 to May 24, 1686, the date on which the lead deposit was found.

THE DIARY OF SIEUR DE TROYES

On May 12th—We reached 'Mattawan', which signifies in Indian language "Fork of Rivers": one being at a point that the left is to the south, and the road of Ottawa's to the right, which is north. Consequently my road leads me to Temiskamingue. I arrived at this place of Matta-

¹ Primary Native Silver Ores of South Lorrain near Cobalt, Ont., by Edson S. Bastin, Geol. Soc. Am., 36th Ann. Meeting, Washington, D.C., 1923.

² *The Daily Nugget*, Cobalt, 1921, and Can. Min. Jour., Aug. 19, 1921.

wan very early; this gave an opportunity to the Rev. Father Sylvie to celebrate Holy Mass. We were at a point where the Indians were camped, and were making canoes. They seemed to be greatly surprised to see such a lot of people. It had snowed in the morning, but the evening was very nice: I had dined with *Sieur Juchereau* that came from *Michilmakina*, and was going to *Quebecq* in a great hurry to bring news to *Monsieur le Marquis de Denonville*. He had arrived as I was having dinner, and continued his journey shortly afterwards, to gain time on his route. In the same time I ordered *Sieur de St. Helene* with three of our canoes to go and meet *Mr. d'Hyberville*.

On May 13th—It rained, snowed, and strong wind all day; also continued the next day till noon. *Monsieur d'Hyberville* arrived and told me he had uselessly waited for two days for the canoe I had made him wait for.

I was very suspicious of the Indians; consequently in order to keep my staff on the watch, I had ordered that nobody on the guard should sleep, and on the first alarm, they were to put out a small fire, and in one word everybody was ready and in order, the arm in hand.

I got a cross erected on the point of the Fork, and our English interpreter opened his leg to the bone with a stroke of the axe. We count from the Island of *Montreal* to *Mattawan* one hundred leagues (or 250 miles).

On May 15th—We could not start before sunrise on account of portaging we had to do in water which was extremely cold. We left after Mass was celebrated, and having made three portages, we camped one league higher than the first, and three and one half from *Mattawan*. One of our canoes was broken in pieces in the second portage. Having landed in a rapid, we saved the contents, but we got some of the staff hurt. I got in the canoe of the Captain of our Guides, an Indian that knew the road of the "Bay" perfectly well. I hired him in *Mattawan*.

On May 16th—We were camped eight leagues from *Mattawan*, one league above the fourth portage. The road is very bad and for three hundred feet long, *Sieur de Ste. Helene* was dragging.

On the 17th—We went up again and the place that we name "The Long of the Soo." It is two leagues long and is extremely difficult on account of its great current. We had to pole it nearly all the way, and dragged it in five or six different places. We got some canoes damaged and we camped above the last rapid.

On the 18th—We left in the morning, and left although there was a big storm that lasted very well near all day. Arrived at the house of *Messrs. The Company of the North*. This company is on an island of *Lake Temiskamingue*: it may have one half a league of circumference and between two rapids proceeding from a little river called "*Matabec Chouan*" in Indian, from which some Indians come out to trade. There were fourteen Frenchmen in this house for the Company that were as joyful as we were of our arrival, that we celebrated from parts and others by several shots of guns.

On the 19th—And two following days, the weather was very unfavourable, *Messieurs de Ste. Helene* and *d'Hyberville* employed with *Monsieur de St. Germain* business of the Old and New Company, and furs that were in the store, where they appointed *Sieur Sibille* to render accounts of all to the company. We left him four men to make the trade with very little provisions. *Sieurs Guillet* and *Villedieu* stayed for three days at *Nipissingue*, *Savage Nation*, to get canoes made and to bring them to *Montreal*. As for us, we traded with the Indians that were close to our house to replace the ones we had, and that we had left there on account of them being too large and too heavy for the balance of our journey. I was very careful to put two good canoe-men for every canoe in order to jump the rapids.

On the 22nd—It rained a part of the day; this did not stop us from going after celebration of Mass, followed by three canoes to go and visit a mine at six leagues from the house. I gave orders to *Sieur de Ste. Helene* that I left, to settle the affairs and to join me the next day with the balance of the staff, and to keep in the Lake the route of the North, to facilitate his joining me. Two leagues from the house, I met three Indian camps that traded a small canoe of four places with me, that I made use of the balance of my journey and for my route to *Quebecq*. I camped from there on an island: weather not permitting me to go farther.

On May 23rd—After Mass we walked to search the mine. The man *Coignac* guided us. We met in our search an Indian camp in which the people the previous day had killed a big moose. This gave me an opportunity to camp close to them, and in order that *Coignac* would find the mine easier. He looked for it uselessly the balance of the day: during this time the two lieutenants left the house to join me with all our staff, but a big storm separated them; ones took the south and others took the north. One part got on islands, this was the cause of very few joining me.

On May 24th—A very heavy wind all day accompanied by rain: but *Coignac* that had renewed his memory assured me that he recognized himself and that the mine was very close. I got in canoe with him: I paddled in bow and he steered and did not quit our search, although the weather was very bad, to go to the place where *Coignac* thought the mine was. We found it; indeed this mine is situated to the east and west on the borders of the lake, west of a rock in form of half circle that has fifty feet on the edge of the water, ten feet high from the level of the water, and one hundred feet deep, having no earth on it and losing itself under a mountain covered with rock. We extracted a few small pieces with great difficulty and returned to the camp.

TIME OF THE RE-DISCOVERY

There are no illustrations or drawings in existence which deal with the mine as it appeared more than two centuries ago. Indeed there is but meagre mention made of the deposit until about 1850. It was about this date that Mr. E. V. Wright of Ottawa, who owned the timber in this locality, rediscovered the deposit.

Wright was engaged in removing timber from his concession when the calks on his boots chipped off some of the galena and lead-bearing ore. Samples of the ore were taken to Ottawa where they lay for several years on the desk of the discoverer. About 1870, it occurred to Wright to have the samples assayed. The result of the assay was such as to arouse considerable interest. Shortly after this, Mr. Wright, accompanied by J. M. Courier and Mr. Eustis from Boston, came up and commenced work sinking a shaft to a depth of about 12 feet. From this shaft they took out about ten tons of ore. Details of the result are lacking. It is recorded, however, that a second shipment was made by raft, but the crude conveyance smashed up in a mad plunge through the rapids at Deux Rivières.

Nothing was done until 1885, when George Goodwin, of Ottawa, together with G. T. Brophy advanced sufficient money to pay for sinking the shaft a further 50 feet in depth as well as installing some mechanical equipment and a five-ton stamp mill. This plant was afterwards burned. No ore was shipped as a result of this work.

About 1890, Robert Chapin, at that time president of the Ingersoll Rock Drill Company (N.Y.), bought the property and made an option payment on the basis of \$125,000. He installed the first air compressor in the country, and built a fifty or sixty ton mill. He continued the shaft to a depth of 250 feet and did considerable lateral work. This resulted in the shipment of a considerable quantity of concentrates, the value of which seems to be impossible to ascertain at this date. It is said that Mr. Chapin became involved in some bad investments which caused him to abandon this mining project with the result that the property reverted to Wright, the principal holder.

In 1895, Wright sold the property to the Petroleum Oil Trust of London, England. The new owners sunk the shaft another 5 feet in depth and did several hundred feet of drifting and cross-cutting at the bottom level, as well as some work at the 250-foot level. The mill was also operated, the concentrates being shipped to Swansea, Wales. No figures are available as to the amount of concentrates produced.

The mill and buildings as erected by the Petroleum Oil Trust are still standing, although the machinery has been pretty well all removed. The writer visited the mine, June 18, 1921, together with the members of the Ontario Mining Association who were being entertained by the Timiskaming Mine Managers' Association. These buildings are of the old-fashioned type, features being the many gables as well as having a ground floor entrance and a second storey entrance by stairways leading from the ground.

A few years ago, the Wright Mine was bought by the Timmins-McMartin interests of Montreal, and is still owned by them. The underground workings are filled with water, the plant is completely dismantled, and the visitor finds difficulty in throwing off a feeling of peculiar sadness as he views this neglected strange link between Canada of the present day and the wild land of 235 years ago, long before Wolfe took Quebec, and even dating back nearly a year before La Salle, the greatest perhaps of the French pioneers to North America. It was in 1682 that history tells us that in the name of France, La Salle took possession of all Louisiana, from the mouth of the Ohio to the Gulf of Mexico in a resounding proclamation handed down to us. On the column was inscribed "Louis le Grand, Roy de France et de Navarre, regne; le neuvième Avril, 1682." It was four years later that the Wright mine was found, thus linking itself with a past about which only a little is known and which occupies but a dim place in the minds of men.

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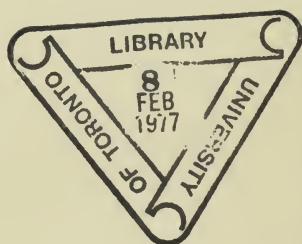
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